NON-ROCKET NEAR SPACE INDUSTRIALIZATION: PROBLEMS, IDEAS, PROJECTS

2021

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Astroengineering Technologies LLC
Unitsky String Technologies Inc.

NON-ROCKET NEAR SPACE INDUSTRIALIZATION: PROBLEMS, IDEAS, PROJECTS

Collection of Articles
of the IV International Scientific and Technical Conference
(September 18, 2021, Maryina Gorka)

Minsk
StroyMediaProject
2022

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Opening Speech by A. Unitsky,

Chairman of the Organizing Committee of the IV International Scientific and Technical Conference "Non-Rocket Near Space Industrialization: Problems, Ideas, Projects"

The IV International Scientific and Technical Conference "Non-Rocket Near Space Industrialization: Problems, Ideas, Projects", like the previous conferences in 2019 and 2020, is held in the surroundings of the picturesque Belarusian nature in the territory of Unitsky's Farm Enterprise, better known today under the brand "Aquarelle EcoPark".

Here, in the territory of the former tank range, everything became even more beautiful, as the experiments to improve the biogeocenosis, flora and fauna of the surrounding living environment are in full swing. We use only green technologies (working without chemical fertilizers, pesticides, genetic engineering, and genetic modification). These technologies are also applicable in the future for the settlement of orbital EcoCosmoHouses that will accommodate and provide a job for millions of people who serve the space sector of the Earth's industry.

The COVID-19 pseudopandemic and related events in the world made me wonder: does the Earth's technogenic humanity have a future at all? And is it necessary to relocate industry into space if tomorrow this industry will not exist on Earth, and the human population by that time will reduce to the so-called "golden billion" and degrade, i.e., it will gradually turn into digitized serfs to serve the "diamond million" according to a certain plan, which has been implemented for decades by the "world elites"?

> **The Earth's human civilization can not only be saved but also set the driver for its sustainable development for millennia to come in compliance with the EcoSpace program approved at the previous conference.**

That is why, in preparation for the conference, I conducted a study called "Civilization Capacity of the Space Home Named Planet Earth".

While working, I analyzed about 100 planetary, biospheric, and civilizational parameters and criteria. As a result, the report turned out to be extremely voluminous. For deep understanding of the essence of my reasoning, I had to visualize it, reducing it several times and presenting in the form of an hour and a half long science fiction film.

It purposely does not include complicating figures, facts, and conclusions. In order that this information, which concerns the destinies of all people on the planet (including us, present here, as well as our children and grandchildren), was perceived adequately by the participants of the conference, I offer you some explanations.

The global pseudo-elites, seeking to preserve their wealth and power, intend to reset the technocratic vector of civilization development, as well as civilization itself. The basis of their sophisticated plan is the claim that civilization has reached the limits of growth and economic capacity of the planet. So, we must undermine these pseudoscientific myths and show an alternative that does not involve paranoid forms of restraint on our civilization development.

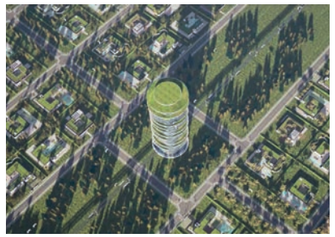
Criteria for the Limits of the Planet Economic Capacity

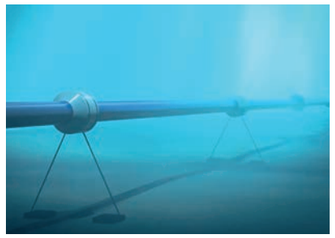
The Earth's human civilization can not only be saved but also set the driver for its sustainable development for millennia to come in compliance with the EcoSpace program approved at the previous conference. This requires action in the following directions.

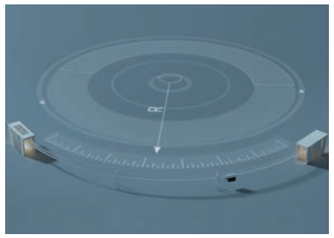
Firstly, agriculture should be localized in places where people live, making it highly productive and completely organic.

Secondly, all Earth's transport should be elevated to the second level, so that it becomes significantly more efficient, safe, and environmentally friendly; at the same time, its cost and resource intensity should be reduced by many times.

Images from the film "Civilization Reboot: Version by Unitsky"







Third, it is important to make the Earth's power industry biospheric. Power plants should produce not acid rain as a waste product, but living humus, which will make up the basis for the fertility of any terrestrial soils.

Fourth, residential and industrial infrastructure should be located in linear cities, which will occupy the land conditionally, as gardens will blossom on the roofs of their houses (in greenhouses). Natural biogeocenoses and biosphere ecosystems will be created there, even in place of the current deserts and permafrost. Houses in linear settlements (which are 2 bln buildings for 10 bln people) will occupy an area of 200,000 km^2, or only 1/750 of the Earth's land.

Biosphere and Industrial Resources

The home in which humanity lives is not the entire planet Earth, but only a small part of its biosphere. Biosphere and technosphere occupy the same niche in space and time. There is a fight going on between them for resources – vital (biosphere) and technological (technosphere) ones.

Flora makes up 98 % of the Earth's total biomass. The primary resource and the main nutrition for it is biohumus, which, as the final waste of the vital activity of all living organisms, accumulates in the soil. It contains all the chemical elements and compounds necessary for life in the form of insoluble organic humates. At the same time, about a trillion laborers work in each kilogram of natural humus, forming a complex symbiosis of several tens of thousands of species of soil bacteria and microorganisms; without them, the normal existence of terrestrial biogeocenoses would be impossible.

The key resources for the industry are mineral and energy raw materials. The technosphere is not capable of creating its own (similar to biospheric) closed trophic chains with trillions of microscopic robotic substitutes similar to microorganisms in the terrestrial biosphere, functioning at the atomic and molecular levels.

That is why any technogenic civilization will inevitably perish as soon as it processes all non-renewable resources limited by the size of the planet into the products and industrial waste it needs.

The Earth's civilization and planet Earth are no exception. Based on a number of forecasts, we will approach the critical milestone already in the 21th century if the vector of industrial development of mankind is not changed and the hazardous part of the Earth's industry is not relocated into near space.

Safe Capacity of the Earth's Power Industry

If the power consumption per capita increases to 5 kW in the future, then (taking into account the proposed biospheric optimization of the Earth's power industry) such a process will not have a negative impact on the biosphere even with the growth of the global population to 70 bln people. To prove this conclusion, it is worth looking at the cyclical fluctuations in the power of solar energy falling to the Earth that are completely safe for the environment. These fluctuations have been within the same limits for thousands of years – 350 bln kW.

Relict Solar Bioenergy

The reserves of oil shale on the planet are estimated at 650 tln tons. With an energy consumption capacity of 5 kW per person, the available reserves of shale are enough to provide 100 % energy to the entire world population of 10 bln people for 5,000 years.

Shale, brown coal, and peat can be used not only to generate electricity but also to form biohumus. Only 2 % of the relict biohumus in the soil – and even the desert sand will become fertile. About 500 tln tons of biohumus can be produced from shale, brown coal, and peat. Such a volume is optimal to turn territories into black soil farmland, the size of which is about 100 times the area of the entire Earth's land. This means that even if the population of EcoCosmoHouses reaches 10 bln people, food security will still be guaranteed as our native planet is able to feed everyone for 50,000 years by supplying biohumus into space.

Safe Carbon Capacity of the Earth's Atmosphere

Relict solar bioenergy involves the release of carbon dioxide into the atmosphere. However, here's the question: how much CO_2 is safe for life on Earth?

Studies have shown that the current level of carbon dioxide in the Earth's atmosphere required for effective photosynthesis is three times lower than optimal. This is evidenced by data on the CO_2 content in commercial greenhouses, where the best yield is observed at a concentration of 0.12 % or more. The volume of CO_2 in the Earth's atmosphere today is about 0.038 %. Carbon dioxide is an indispensable atmospheric resource for the entire flora of our planet, it promotes the growth of forests, increases crop yields,

accelerates the growth of fish, as well as shellfish and corals in the seas and oceans. In addition, CO_2 increases the production by flora of another most important waste of planetary homeostasis – oxygen, which is necessary both for our breathing and for the existence of the industry we have created. Thus, the current global level of industrial CO_2 emissions is about 30 bln tons per year (i.e., about 1 % of its content in the atmosphere) is completely safe for the biosphere and is not only nonredundant but does not even make up for the biospheric carbon deficiency in the Earth's atmosphere.

Food Capacity of the Biosphere and Settlement of People

The basis of food production on the planet is living fertile soil. A person eats about 700 kg of food per year. As a result of metabolism, a person releases the same mass of waste into the environment, primarily through the digestive system. If the waste converted into biohumus is brought back into the soil on which the crop was grown, then we will thereby restore the natural cycle of living matter disrupted by modern cities with their traditional sewage system. After all, currently food grows in one place, and waste is generated in a completely different place, thousands of kilometers away.

Therefore, the pattern of the settlement of people on the planet should be changed towards optimization. Cities and roads have already occupied huge spaces: territories exceeding six times the area of Belarus are "buried" under asphalt and sleepers. And one megacity – the Chinese industrial city of Chongqing – has already surpassed Austria in size, capturing more than 80,000 km^2 of land from nature.

Linear cities will become an alternative to modern megacities, not only preserving fertile land for nature but also creating more of it (in particular, through solar bioenergy, the by-product of which is highly fertile biohumus).

The roofs of the "horizontal skyscrapers" in the linear city will be made in the form of glass greenhouses. Such a solution will allow us to cultivate vegetables and fruits on the roof; to breed marine and freshwater fish, seafood, as well as to grow mushrooms, poultry, and other products on the basement floor. This means that every house will be able to provide year-round organic food to the people living in it.

Biosafe Capacity of the Biosphere and a New Social Evolution Level of Human Development

When 10 bln people will live and work on the planet, the mass of all mankind will be only 1/20,000 of the total terrestrial biomass. Such a ratio will not lead to global problems if we stop fighting Live Nature. Problems are created not by the Earth's population itself as a biomass, but by the technosphere. It, like a cancer cell, destroys its host, in this case, humanity and, accordingly, the biosphere, which occupy the same spatial niche. The technocratic vector of development is heading to a dead end not because of humanity as such, but because of the imperfection of outdated engineering technologies that do not meet the civilizational requirements of our days.

I see the main reason for global problems in unreasonable development of civilization. At the same time, we are smart enough. However, mind and reason are different manifestations of intelligence. The reason is responsible for spirituality – self-knowledge, self-development, feelings, morality, ethics, culture, improvement of relations between people and nature.

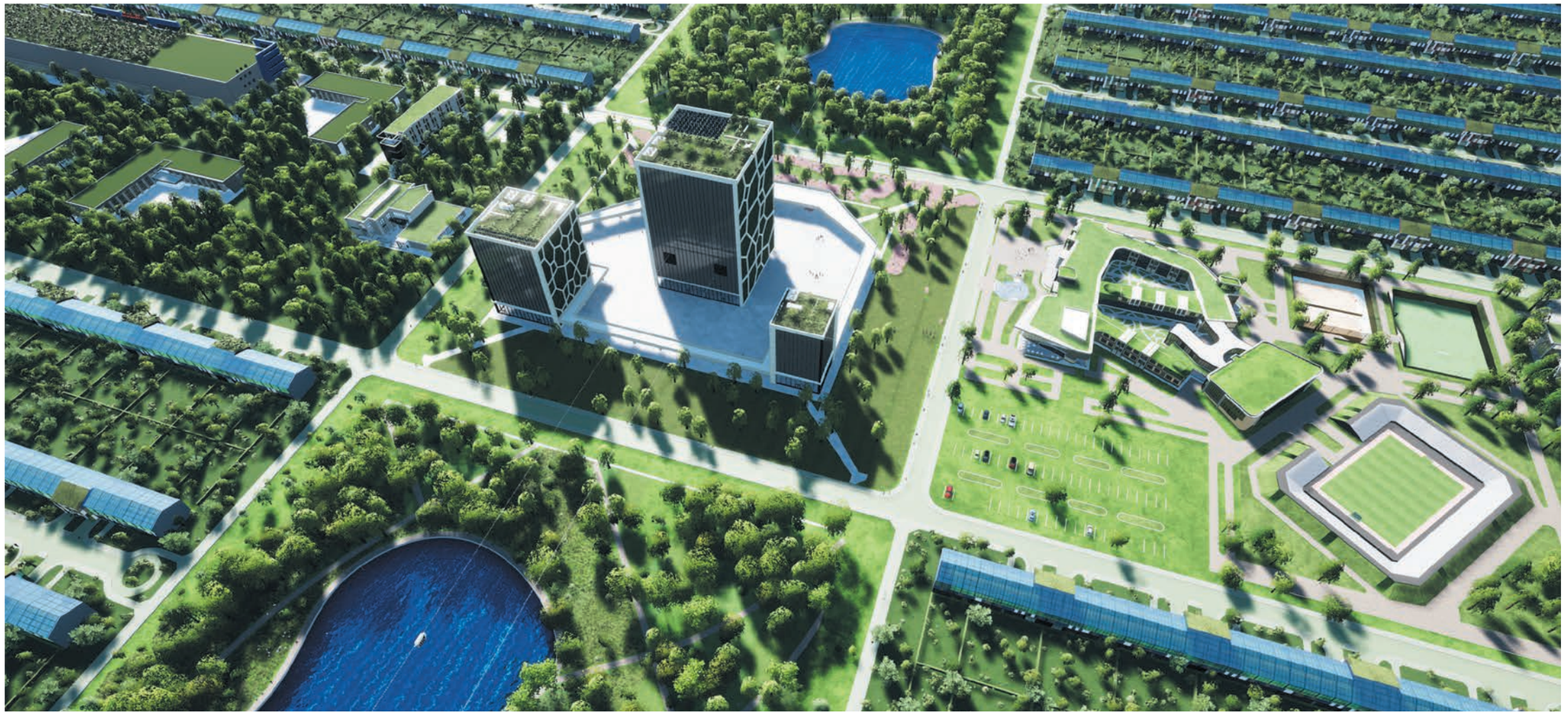
The real progress of mankind should consist not so much in industrial achievements as in the progress of humaneness in people. A reasonable civilization is able to competently dispose of limited Earth's resources. It will manage to find solutions to bring the industry out of the living biosphere into the dead space. Mankind must have time to carry out this important mission before the point of no return, when it will be too late to change something on our planet.

We need to implement a civilizational reboot. The starting point will be to build first targeted projects as part of creating a fundamentally new planetary eco-infrastructure, which is "second level" string-rail transport, linear eco-cities at the first level, and relict solar eco-biopower plants, which will produce fertile biohumus as the industrial waste.

The above analysis shows that the entire future humanity of about 10 bln people will be able to live comfortably and safely on our planet.

We need to start thinking and acting on a cosmic scale. By the middle of the 21th century, a large-scale industrialization of near space should be carried out. The resources of the Solar System are sufficient to satisfy every technological need of mankind for millions of years to come. It is necessary to finally choose the biospheric path of sustainable development of our technogenic civilization in the logic "Earth is for life. Space is for industry".

Based on these life-affirming civilizational goals, objectives, and programs, I declare that the IV International Scientific and Technical Conference on Non-Rocket Near Space Industrialization, which will certainly go down in history, is open.



Welcome Speech by Hussain Al Mahmoudi,

CEO of the Sharjah Research Technology and Innovation Park and American University of Sharjah

Ladies and gentlemen! Today we are participating in the IV International Scientific and Technical Conference "Non-Rocket Near Space Industrialization: Problems, Ideas, Projects". I am pleased to share with you this significant event dedicated to the exploration of outer space.

At this event, I represent the Sharjah Research Technology and Innovation Park (SRTIP), located in the United Arab Emirates. I want to say that I am proud of my cooperation with Dr. A. Unitsky, because together we open up new knowledge, opportunities, and horizons. I am inspired by his example: this scientist solves the most important task – he develops new generation technologies that will help humanity overcome many problems, including those related to transport communication.

I believe that now is the time to direct the scientific and technical potential to the non-rocket path of space exploration. We, humans, must do everything to make our Universe more stable and secure. I am sure that the study of space will help to get closer to this goal, contribute to the stabilization of the environmental and economic situation, and also open up many business opportunities.

The UAE Government defines space as a strategic part of development: my country sent a mission to Mars; we have a successfully functioning space agency; we are developing specialized equipment that will allow us to continue the exploration of space. SRTIP has created a single platform accessible to the entire region of the Middle East and North Africa. Its purpose is to support companies that are ready to invest in the industrialization of space; identification of educational institutions that want to gain access to investments and markets; to ensure the performance of organizations and individuals that offer brilliant ideas. We invite you to become part of our system.

The duty of humanity is to preserve our earthly world for future generations, making it better and more colorful. That is why today's event is another step towards saving the planet and space exploration.

The conference, which has been held for many years in the hospitable Belarusian land, has united people who are passionate about such a great idea. I will be glad to see you in Sharjah Research Technology and Innovation Park.

I believe that now is the time to direct the scientific and technical potential to the non-rocket path of space exploration. We, humans, must do everything to make our Universe more stable and secure.

Welcome Speech by Lembit Opik,

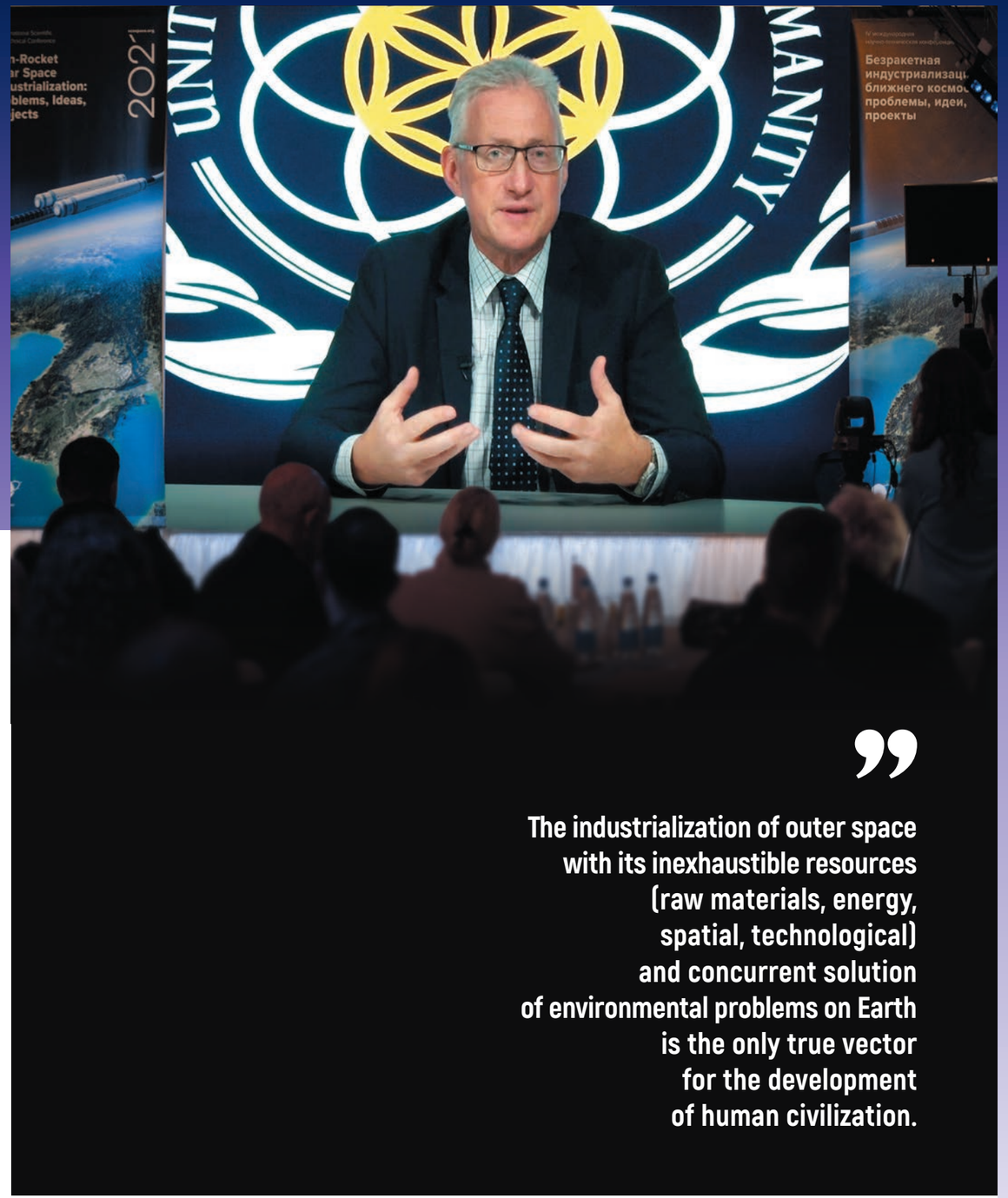
Chairman of the Parliament of the Space Kingdom of Asgardia

Dear colleagues, I have been lucky for the second time to become a participant in the International Scientific and Technical Conference "Non-Rocket Near Space Industrialization: Problems, Ideas, Projects". As Chairman of the Parliament of the world's first Space Kingdom of Asgardia, I share your emotions and aspirations. This event is an excellent opportunity to look at space exploration from a technical point of view.

I have repeatedly asked the question: "How can the industrialization of outer space help in solving global environmental problems?" There has been a lot of political debate on this topic. People are seriously concerned about the human impact on the environment. Moreover, after a few decades and centuries, we will have to find ways to explore space, since it is difficult to predict the growth rate of the Earth's population. It is already clear to everyone today that rockets are not capable of providing the necessary scale. That is why non-rocket exploration of near space is so important, because otherwise it is impossible to create a permanent and self-sufficient space habitat. That is why it is necessary to abandon rockets and use new technologies that will make space financially, logistically, and environmentally accessible in industrial terms.

I have been sharing the vision of Dr. A. Unitsky for a long time, from the moment I first heard about his activities. The General Planetary Vehicle (GPV) he developed is a unique invention, both conceptually and technically. The GPV is the very chance, thanks to which humanity can choose a reliable way of populating outer space and, most importantly, saving and protecting the native planet. The industrialization of outer space with its inexhaustible resources (raw materials, energy, spatial, technological) and concurrent solution of environmental problems on Earth is the only true vector for the development of human civilization.

Consider me part of your team. And I consider it my duty to contribute to the unification of the interested community, i.e., all those who share our vision in the direction of non-rocket space exploration.



The industrialization of outer space with its inexhaustible resources (raw materials, energy, spatial, technological) and concurrent solution of environmental problems on Earth is the only true vector for the development of human civilization.

Welcome Speech by I. Shnurenko,

**writer, journalist, screenwriter,
author of books on artificial intelligence and futurology**

Increasingly occurring weather anomalies suggest that nature is trying to refute people's ideas about it, resisting their impact. At the same time, some concepts of the World Economic Forum imply manipulations with nature and man, they want to change the essence of *Homo sapiens*; moreover, genetically modify it. In my opinion, this is a blind alley.

There is a radical simplification of the global system, there is a hypernormalization of the unnatural state of affairs. With manipulative techniques, we are told that megacities are normal, that this is the way to live, that development does not mean improving quality, but increasing quantity. In Moscow, for example, the launch of a certain number of metro stations is considered an achievement – one ring after another is being built. However, such a heap of infrastructure actually means that civilization has lost its purpose and center for the rational application of its efforts and energy. The core of development should be an engineer-philosopher, whose views and knowledge will help to avoid many problems.

The German thinker M. Heidegger, the author of the concept of technoscience, believed that the relationship between technology and science is inseparable. Breaking everything into pieces, we inevitably lose and go down the wrong path. It is necessary to return the original meaning to technology: the Greek word "techne" (Heidegger wrote about this) includes not only science but also art. The human, i.e., an engineer, is also part of this chain of connections; he must feel the deep principles of the relationship between art, science, and technology.

The new world that we would like to build requires free personalities: not zombified and subject to manipulation, but close to the concept of an engineer.

Looking into the night sky, people often wondered what was beyond that limit, beyond which, as it was believed, it was impossible to reach; they looked into space with hope, faith in the future. Now, unfortunately, there is a dangerous development of space technologies, as a result of which the night sky can cause fear. The space internet, which is imposed on us by the World Economic Forum, by Dr. K. Schwab and other similar experts as one of the key technologies of the Fourth Industrial Revolution, is the internet of bodies, the internet of things, and in this concept, a person is considered as an object totally controlled from space.

Rockets deliver dozens of satellites into space, there are hundreds of them already in near-Earth space, and there will be thousands, because the plans for the next few years include the full functioning of Starlink and OneWeb, the launch of other satellite systems. Their purpose is to provide a so-called connection so that each of us is under control 24 hours a day, seven days a week, wherever we are: in the desert or in a big city. There is a radical simplification of man.

Speaking about a systematic approach, we must understand that only the union of the biosphere and people, the technosphere and technoscience into one organism can make our future worthy. The simplification of the system of interconnections that is taking place today is caused by a misunderstanding of it – as some kind of mechanical or, at best, biological structure that is tuned to devouring.

Based on this approach, companies and banks destroyed Earth, used it as a resource and produced a huge amount of waste. Now these organizations have allegedly reincarnated, but it is impossible to believe in this, because their working principles have remained the same. But a truly systematic approach should be multi-agent, involving the integration of disparate components into a single whole.

The new world that we would like to build requires free personalities: not zombified and subject to manipulation, but close to the concept of an engineer that I spoke about. It is necessary to raise the level of education, engage in enlightenment, bring up worthy people to build a better society and a better future for all humanity, including in space.

Welcome Speech by P. Khrienko,

**Vice-President of the Crimean Academy of Sciences,
Professor of the Department of State and Municipal Administration
of the V.I. Vernadsky Crimean Federal University**

Dear colleagues, I thank you, as well as my friend and comrade Anatoli Unitsky, for the opportunity to participate in this conference. Of course, we, Crimeans, gladly accepted the invitation.

Crimea is considered a special region because it is located in a unique place – on the 48th parallel. Many great ideas were born and realized here. Many scientists who predetermined the development of science worked here: D. Mendeleev, V. Vernadsky, K. Shchelkin, I. Kurchatov. The Crimean Astrophysical Observatory, one of the international centers for observing outer space, is located here, as well as the Center for Deep Space Communications, whose activities are focused not only on studying deep space but also on monitoring seismic and other geophysical phenomena. The potential of the space sphere was often studied in the research works of Crimean scientists. I am sure that is why the innovative ideas of engineer A. Unitsky were appreciated on the Crimean Peninsula – as the most necessary for humanity. In particular, at the general meeting of the Crimean Academy of Sciences held in the spring of 2021, the scientific community, which I now represent, applauded the information about your achievements, which are extremely significant at the present time. Moreover, civilizational processes make these ideas particularly weighty.

**I would like to emphasize:
here and now
we are laying the foundation
for a future prosperous life;
perhaps not for us,
but certainly for our descendants.**

The importance of the exploration of near space is undoubted. This urgent task is due to the global events observed in the modern world. It is obvious to everyone that today there is a transition of humanity to a new socio-economic formation, the creation of a new way of life is intensively going on, as representatives of not only the scientific community but also many ruling elites speak about.

In this regard, the following episodes are most indicative.

Everyone remembers the global, primarily financial and economic, crisis of 2008. The countries were in a state of searching for an optimal way out of the situation. At the initiative of the Secretary-General of the United Nations, 20 leading economists were gathered to analyze the problem that had arisen, who had to decide whether it was possible to overcome the crisis and how. The result of their joint work was the report of the Nobel laureate J. Stiglitz. The introduction of this research work presented an assessment of the current critical situation; the main conclusion was: the neoliberal model of the economy has completed its historical stage of development. At the same time, the experts were unable to identify ways to overcome the existing and ever-deepening crisis. What to do next? There was no answer.

It is appropriate to recall the ideology of the neoliberal political system by Z. Brzezinski, who unconditionally believed that Western civilization is the best that humanity has created. However, in his latest work "Strategic Vision: America and the Crisis of Global Power" he speaks about the "dying West" and even the "decline of the American dream". Before his death, the political scientist concluded: "What I have been doing all my life is a thing of the past. We need to look for a new algorithm for the political institutionalization of humanity."

The political economist F. Fukuyama, in his book "The End of History and the Last Man" (1992), used solely quantitative methods to argue that America and the Western model of development had won. After a while, Fukuyama significantly revised his own point of view and at the beginning of the third millennium he published another work – "State-Building: Governance and World Order in the 21st Century". In fact, this is a kind of repentance – the scientist convinced the reader: neither democracy (the power of the majority) nor the dictatorship (the power of the minority) can save humanity; only rationally and scientifically substantiated methods that adequately perceive and reflect development processes are called upon to become a panacea. That is, there was already a talk about the crisis of modern civilization and the need to strengthen the role and importance of the nation state in solving emerging problems.

As we can see, the world is in a contradictory state. It is increasingly clear that to overcome the crisis, innovative ideas created on a scientific basis are required. At the same time, in foreign and domestic scientific literature, in the statements of political leaders there is only an assertion of the existing civilizational decline. The way out of it, as a rule, is not indicated or is presented on the basis of conservative principles. In particular, when did it happen that the third place in the US presidential election was taken by a person of a socialist persuasion – B. Sanders? It is no coincidence that the book "The Death of the West" by the American politician and publicist P. Buchanan, which has become the most famous in the United States in recent years, claims that socialism will save us.

But I believe that the salvation of humanity lies not in socialism and not in capitalism – it is based on rational system technologies of the engineer A. Unitsky. In the context of today's search for ways to overcome the civilizational crisis, the conceptual model of near space exploration developed by the Belarusian scientist stands out prominently, being the main link that is able to influence the resolution of many socio-economic, political, and humanitarian issues facing people. Moreover, the anti-crisis project proposed by A. Unitsky is philosophically reasoned, bringing biocenosis, sociocenosis, and technocenosis into a single algorithm for further development.

I would like to emphasize: here and now we are laying the foundation for a future prosperous life; perhaps not for us, but certainly for our descendants. I thank Anatoli Unitsky for being the first: being the first is the hardest thing. I thank those who support the pioneer. I am sure, no matter how hard it is on the way, this business will certainly be crowned with success. Success necessarily comes to the persistent, stubborn, and purposeful.

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Civilization Capacity of the Space Home Named Planet Earth

A. Unitsky Astroengineering Technologies LLC, Minsk, Belarus
Unitsky String Technologies Inc., Minsk, Belarus

The issues of global problems of modern times and sustainable development of our Earth's technogenic human civilization have always worried progressive minds. The industrial (engineering) path of human development dates back 2 mln years. From the invention by ancient engineers of stone tools and fire, with which they began to cook food, to the present day, when the launch vehicle and artificial intelligence were invented. And, as an alternative to the forthcoming death of human civilization on planet Earth, our own home, where growth limits and the carrying capacity of the biosphere are allegedly reached, we are now offered to settle down on a strange and remote Mars. We must build a new home where there is no tellurian biosphere and where people will die instantly by historical standards. Or it is proposed to reduce the size of the Earth's civilization to the "golden billion" so that the survivors have enough resources for a comfortable life in the foreseeable future. The author proposes another alternative – to accomplish a non-rocket industrialization of near space, by shutting down the environmentally-dangerous part of the Earth's industry, and transform the planet into a blooming garden. In order to do so, it is required: to replace inefficient "first level" transport with "second level" electric transport and build on the planet the transport and infrastructure network uNet, about 10 mln km long; switch the world power industry to relict solar bioenergy, whose "waste" will be vegetables and fruits; to build along the uNet network linear cities (uCity), dovetailed with nature, with a total length of about 5 mln km, where all future Earth's humanity, about 10 bln people, will live and work comfortably and safely for millennia to come. To achieve these global goals, humanity itself should change – it will have to rise to a new level: to make a transition from a techno-consumer society to a socio-technogenic civilization.

Keywords:
biosphere, technosphere, technogenic human civilization, global problems, economic capacity of the biosphere, growth limits, linear city, relict solar bioenergy (RSBE), Unitsky String Transport (uST), General Planetary Vehicle (GPV), society, spiritual development, "Earth is for life. Space is for industry".

Introduction

Man chose the technological path of civilizational development about 2 mln years ago when he created his first engineering technologies, including lighting his first fire and starting to cook food on fire [1].

At the present development stage of engineering technologies "Technosphere 1.5" (from the third quarter of the 20th century till now [2]), many myths have emerged that are related to the rapid development of the Earth's industry. These are global warming and a geoclimatic disaster, a critical shortage of resources and pervasive pollution of soil, water and air, intense destruction of the ozone layer and an excessive risk of pandemics, a significant overrun of the growth limits and "economic capacity of the biosphere", unacceptable overpopulation of the planet and many, many other civilizational "tales of terror" – one being more terrible than the other.

That is why the main goal of this study was a desire to warn people against the danger poised over all of our heads and to show the technological path to a civilizational way out of the critical situation on the planet. At the same time, the defining driving motive for the author is the impossibility of continued silence and obedient humility in relation to the destructive changes happening in the world today, in a situation where not only almost all the basic values of our civilization but our very future is under a genuine threat.

A hybrid war has been declared on all modern humankind by means of neurolinguistic reprogramming from the existing civilizational vector "Technological and intellectual progress" to the destructive vector "Personal, social, and civilizational suicide". This war is being waged with the help of digital information tools and media, which have changed the principle "Truth is the most important" to a more monetized one "I serve the master".

This plan is being carried out in the interests of the real owners of money – oligarchs-globalists, the so-called "deep power" – those who secretly rule our world through powerful trillion-dollar financial levers. Preparation for this war, triggered by the 2020 pseudopandemic, took more than one decade, and even more than one century, starting with the cleric Thomas Malthus with his "Malthusian trap" [3] – his work on birth control, including through forced sterilization, was called "The Genocide Sermon".

We, ordinary people, can still be protected by our nation states. They have all it takes to do this. The innovations with the help of which it is possible will be sufficiently detailed below:

- intensifying the development of our technocratic civilization along a creative path;
- solving all the environmental and social problems without harming the planet and its biosphere;
- raising the standard of living in any country and humanity as a whole;
- giving all of us a chance for a better future – safer, more comfortable, and more humane.

However, a few words should first be said about the anti-human plans articulated by the so-called "global elites".

Problem

Our panhuman civilization has once again come to a deadlock. In all previous similar cases, this resulted in wars, economic and social crises. Empires collapsed, the world map was redrawn. Afterwards, on the ruins, nation states were ever so slowly restoring social and political life, while accumulating problems and contradictions in a fashion that each new shock was more dreadful than the previous one. Time and again, humanity has fallen into the same socio-economic "trap".

Now we have come across the coronavirus. No matter how hard they try to serve it up to us as a sort of natural mega-calamity, one can patently see this is not so.

First, it is clear that the pandemic is the aftermath of the devastating human impact on nature, the immense and nonsensical consumption. Examples abound. The virus is believed to have spread to humans from animals. The blame is assigned to pangolins, according to one version. These animals are in high demand with the Chinese foodies – nourished and even satiated people. Because of this, pangolins came to the brink of extinction. It has long been not about hunger. Pangolin meat is a luxury item, an element of upmarket consumption.

Likewise, because of humans, thousands more, if not millions of other species of animals, plants, and microorganisms are on the brink of complete extinction. About three species of living creatures disappear from Earth every hour. The planet is merely defending itself from offensive people. Pandemics of the future will be way more dreadful than the current coronavirus pseudopandemic.

Secondly, it is our way of life, which, along with the yoke imposed on nature, makes humanity the main culprit in the emergence of pandemics:

- we began to settle in large numbers in cities where a great many people are in close contact with each other. At the same time, cities are served by obsolete – one might say ancient – transport systems, in which urban, intercity, and international transportation involves large gatherings of people in public places, means of transport, train stations, and airports;

- it is faulty nutrition and unhealthy lifestyle (physical, spiritual, and moral) which weakens and destroys our immunity. But immunity is our main "medicine", which cannot be replaced with any of the medicines invented by humans, including those taken as vaccines and inoculations.

It is easy to notice that these same two main reasons are the source of all the most massive shocks of the recent centuries. All the wars and economic problems of the 20th century occurred because of overcrowding and a persistent desire to consume as much as possible, resulting in the escalation of the struggle for resources and spheres of influence. This struggle is one of the basic elements of a capitalist system based on profit and around profit.

In general, the capitalist system implies the need for and imminence of crises, which each time lead to more and more disastrous consequences. Most economic experts agree on this. To this date, knowledge about this has become widespread, right down to the level of the layman. Accordingly, there is a demand for the reform of capitalism, since alternative models (for example, socialism) are not accepted by the global elites. After all, these are the capitalist elites. They cannot disown themselves.

Since crises are mainly associated by experts with overproduction of goods, they can only be avoided by changing the nature of production and consumption. Before exploring how exactly they intend to arrange the new world, it is necessary to understand how all this is happening now. Only in the most general terms.

Enterprises manufacture goods, pay workers for their labor, and keep the added value, in order to then spend it on the development of production, their own needs, and the needs of the state in the form of taxes. That said, the goal of any production is to increase profits, which is achieved, on the one hand, by optimizing technological processes and reducing the cost of labor, on the other, by increasing the quantity of manufactured goods.

Therefore, the volume of production should increase all the time, and the relative wages for labor should decrease. At the same time, it is hired workers who buy most of the products. If they earn less, they buy less. And more and more goods and services are being produced. At some point, there are so many of them, so nobody needs them and the manufacturers cannot sell what they have produced in order to pay off the investments. Then they opt

for staff redundancy, assembly line shutoff, and production minimization.

The economy sinks into crisis. Then someone goes bankrupt, someone optimizes something, prices drop for the accumulated surplus of goods, chock full warehouses gradually empty, and then there is a demand again that exceeds supply. Everything is repeated at a new stage. A war or a pandemic, by the way, can significantly mitigate the situation, as in a short time they create new market outlets, job opportunities, a request for certain product ranges, orders, and the like. Therefore, wars begin the moment the economy reaches its peak. This is not an effect of an excess of power, but a way to avoid the upcoming steep and painful fall from the top. But is it possible to avoid crises in some other way? It is supposed to be so.

It is assumed that it is possible to improve the capitalist system, to make its development stable instead of cyclical (from crisis to crisis). To do so, it only requires to organize production and consumption so that they are always balanced and ordered. But, of course, not in the planned economy logic, but by providing the ability for the capitalists to preserve their power and wealth.

Digitalization should come to the rescue, being a digital transformation of society and economy. Most notably it's about the Internet technologies, big data processing technologies, virtual and augmented reality, artificial intelligence, 3D printing, printed electronics, blockchain, quantum computing, and the like.

Digitalization will help to get total control and accounting: what and how much is produced, what and how much is bought. It will also form the basis of a new – inclusive, i.e., "universal" – capitalism, where an ordinary person will no longer own anything (no private property), but will only use services. And, because life will turn out to be unthinkable over time without these digital services, the demand for them will become constant, increasing in proportion to consumption, without any fundamental restrictions (and there will be none, since everything will take place in a virtual digital environment, and not in a world of material objects that has limits and boundaries).

Digitalization is one of the five pillars on which a new world order is planned to be built. Along with it, one can also speak of the four "Ds": **depopulation, desocialization, deindustrialization, decarbonization.** With their large-scale postcapitalist deployment, these vectors of development proposed by modern capitalism are likely to ensure the stable development of the system. However, this "brave new world" will turn out to be simply horrific from the point of view of circa 7 bln people for whom there is no place in there. The substance of such plans is as follows.

Digitalization is the basis. Within the logic in which it is developing today, this is an absolutely dreadful tool. It includes:

- introduction of widespread accounting and control systems at the place of production, in the service sector, in the banking sector, and so on, which will lead, in the end, to the introduction of total control over the "wrong people" and the transfer of a number of civilizational functions to the supposedly "smart", but in fact primitive artificial intelligence, from an engineering point of view, which is several orders of magnitude below the complexity of the structure of the simplest microorganism, such as coronavirus;
- accelerated introduction of bioengineering technologies, the mass production of robots, the promotion of projects on genetic mutations and crossbreeding of species, as well as the interbreeding of people, artificial intelligence, and machines, which will lead to a gradual transformation of the human personality into a soulless human-like creature – into a cyborg, into a bio-digital convergent.

Desocialization is:

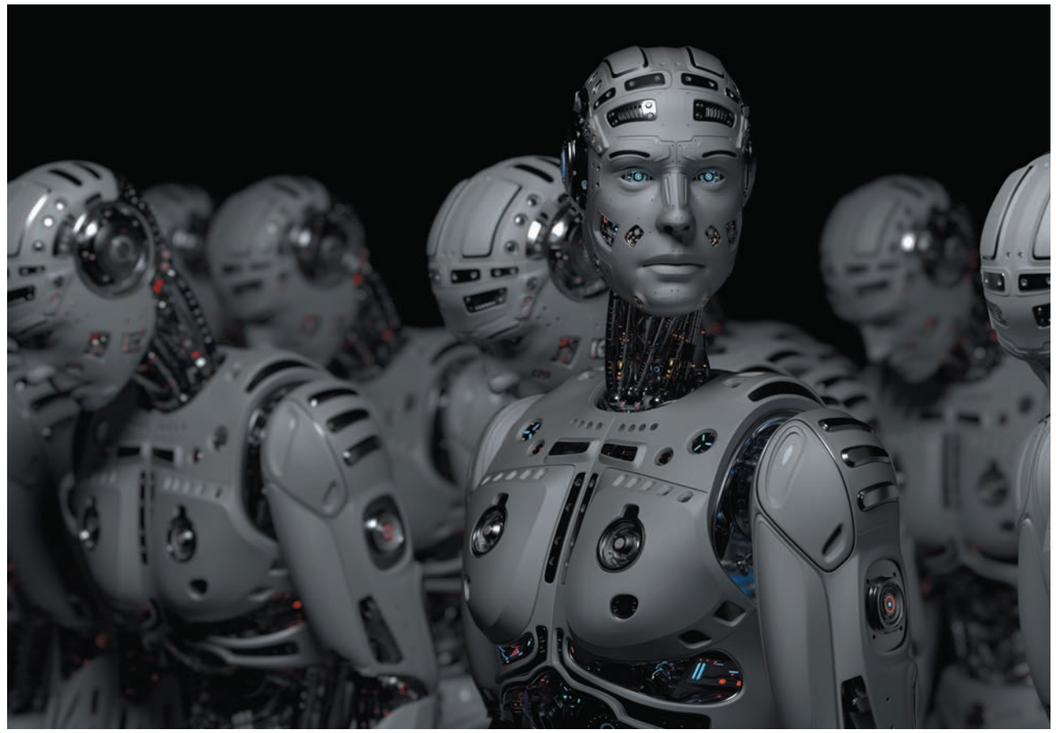
- establishment of a new gender policy, glorifying minorities (social, ethnic, racial, biological, and gender) where minorities dominate over the majority;
- subordination of humanity to liberal values, opposition to critical and analytical thinking of people, deprivation of privacy and civil rights, total censorship, complete control and manipulation of the media, social networks, as well as consciousness, ideology, education, science, culture, art, and religion. After all, decrepit and dying capitalism needs primitive convergent consumers, not creative individuals. Moreover, there will be a gradual decrease in the role of nation states in the life of society, the transfer of most of their functions to global corporations;
- fight against natural childbearing, elevation of bodily and spiritual ugliness and perversion, depravity and lust, along with mentally and physically handicapped people to an ideal of harmony and beauty;
- destruction of the institutions of the family and nation states, which must be replaced by global (supranational) corporations that have entered the totalitarian phase of their development;
- expanding the influence of Big Pharma transnational corporations that are not interested in human health, since only ill people can bring profit;
- clearly defined incremental introduction into social consciousness over many decades of the guilt complex, i.e., a complex of personal and collective inferiority. We, normal people, who are the overwhelming majority, are forced on all continents to repent, to feel guilt, inferiority, and faultiness at the slightest pretext: for the fact that we are not homosexuals; for the fact that we have light, not dark skin (or vice versa); for the fact that we have this or that nationality; for eating meat and opposing genetically modified and artificial foods; for doubting the benefits of vaccination and, in general, whether there is a pandemic? For having a family, a mum and a dad, for using the words "man" and "woman", "he" and "she"; for being healthy and not disabled; for not believing blindly in global warming and the carbon greenhouse effect – this list of our "guilt" goes into infinity. In its social essence, it is a psychological terror unleashed on every person and humanity as a whole.

Society is gradually and fairly consistently transforming (or rather, it is being transformed) into a kind of turbulent, albeit aptly managed, set of minorities dissatisfied with life, who originally, from the early childhood, are upset with the "alien" majority. The majority of society, even to the detriment of its own interests, must constantly take care of these people wronged by life, and the interests of minorities, including the frenetic desire to dominate over the majority, should not be questioned and criticized, otherwise it immediately falls into the category of racism, homophobia, or xenophobia.

This reminds the author of the story of any cancer cell that, with its "unconventional values", misleads, i.e., deceives, the weakened immune system of a healthy organism with billions of normal cells, and ultimately kills its master, and dies itself by metastasizing into all organs.

The displacement of small companies and industrial enterprises from the market will lead to the emergence of global monopolies, which will be free to dictate any favorable conditions to the consumer.

The erosion of the functions of the state and their transfer to global corporations will lead to a revision of social policy and social hierarchy. For example, why pay pensions and, in general, do corporations need disabled old people and children, hospitals and roads, and the entire social infrastructure altogether? Therefore, in accordance with the new standards, consumption, childbirth, and other manifestations of human life will have to be rationed.



Allegedly, this is the only way to support the "sustainable development" of the proposed "brave new world".

Reducing the importance and role of the nation state is necessary for the beneficiaries of capitalism in order to pay less taxes and, at the same time, to increase the demand for goods and services provided to the population in many countries at the expense of these same taxes. This is about the removal of the intermediary that reduces the efficiency of the capitalist system and adds unnecessary variables to it.

Desocialization, along with the fact that, by detaching from society, it makes each individual unprotected in the face of global corporations, deprives him of the hope of receiving help and support from loved ones who could pass on to him certain necessary knowledge, experience, goods, or services. Naturally, he will have to singlehandedly purchase everything he needs, therefore, as the consumer, he becomes much more reliable and efficient from the standpoint of making a profit off him.

That is why, under various glib excuses, there is an accelerated elimination of competitors of global corporations (small and medium businesses, personal and private property) with the transition to a supposedly more "advanced" sharing economy.

Deindustrialization is:

- redeployment of almost all sectors of the world economy into a vague and opaque sphere of environmentally safe production, running in parallel with the monetization of the environment itself and its transformation into capital for a narrow circle of globalists. There is a widespread change from traditional nature conservation activities to environmental extremism;
- accelerated reduction of industries and workplaces (especially intellectual and high-tech), the creation of a civilizational "digital concentration camp" with a global lockdown and payment of a guaranteed (basic) remuneration, i.e., the minimum "ration" (as in any other concentration camp) to those who will not go to work;
- curtailment of the traditional (natural) production of agricultural products and transition to artificial and genetically modified foodstuffs (in particular, to lab-grown meat, which is dangerous to human health and is inferior in its contents and quality). One of the main arguments used is that a cow is allegedly more environmentally dangerous than a car and an airplane, since it emits a lot of greenhouse gases, including carbon dioxide and methane, so humankind will have to supposedly give up on beef in the near future.

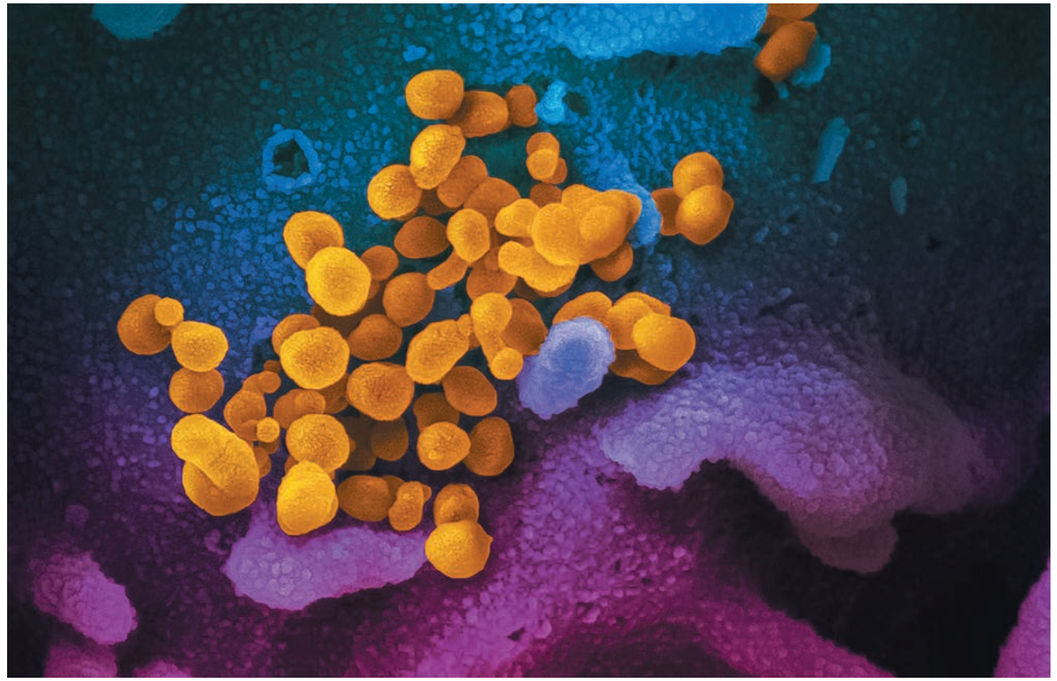
Decarbonization is a rejection of hydrocarbon fuels – oil, coal, natural gas – and CO_2 emissions into the atmosphere, replacing them with supposedly green power technologies – ineffective and environmentally no less dangerous.

Decarbonization and deindustrialization are interrelated elements of the same program. In a broader view, they refer to the monetization of ecology, its transformation into capital. People and businesses are therefore forced to pay for the things we need most, such as water and air, whose value becomes part of the surplus value. The demand for this product will be more stable, which will reduce the risk of overproduction. On the other hand, the slowdown in industrial development is a highroad to a decrease in the real incomes of the population and, as a consequence, to a decrease in its total number, which is one of the goals of the elites, defined as **depopulation.**

The "sustainable development" thesis of the Club of Rome [4] assumes an accelerated reduction in the world population to the "golden billion". Hence the special operation "COVID-19 Pandemic" with facemasks and all-round lockdowns that destroy families, the immune system of people who are willy-nilly put in a "home prison", and destroy small and medium businesses – the basis of the economy of any country. In fact, it was an epidemic like influenza, known to humankind since the 12th century, but vilified and elevated to the rank of a pandemic in the 21st century by unscrupulous media under the management and control of oligarchs-globalists.

Matrix RNA vaccination, yet to be properly studied (in terms of its long-term consequences), which is also carried out supposedly by the most "humane" self-imposed compulsory methods, also logically fits into depopulation. Over time, this can lead to irreversible genetic changes in the vaccinated organism, including negatively affecting the male and female reproductive organs. In its social essence, such "treatment" can be used, if necessary, as "velvet genocide", i.e., prolonged murder. Although, most likely, we will not know when such a "need" will arise.

For example, vaccination is supposed to lead to collective immunity, although in the documents of the World Health Organization this is called "herd" immunity. Humanity is just a herd in which it is necessary to replace the natural immunity, uncontrolled by third parties and polished over billions of years of evolution of life on the planet, with externally controlled artificial immunity. We are meant to get hooked on mandatory vaccination – a strong addiction, akin to a drug one, to the need for a lifelong intake of questionable vaccines, constantly mutating like the virus itself. It will become another step towards turning people into cyborgs.



Depopulation is also required for the simple reason that due to the automation of production and similar innovations, capitalism as a social system does not need a large number of people for its functioning. Moreover, an excess of human biomass is dangerous for the system, since those individuals who are not involved in production will nevertheless need goods and, moreover, demand them. Therefore, it is better to optimize the size of population (on top of all, at its own expense) in such a way that it would provide sufficient volumes of demand and would be involved in the production of what it itself consumes. That is, the population should be able to feed itself and, at the same time, guarantee an increase in profits and luxury to the global elites, but nothing more.

The world order described above is a global digital concentration camp, digital fascism. Such a system, offered to us as an image of an inclusive future, will be strictly ordered and self-sufficient. The main difference between such a "brave new world" and the existing world order is stability (as opposed to cyclicity). That is why globalists repeat like a mantra the phrase "sustainable development" – like some kind of spell from black magic. At the same time, they use every effort to pretend that their actions are motivated only by global environmental problems and concern for people. In fact, the reasons are different, but the ecology is just a good product. Perhaps the best planetary business resource available to us.

For example, Prince Philip, the late husband of Queen Elizabeth II, one of the ideologists of the decrease in the planet population, talking about his rebirth back in 1988, said: "In the event that I am reincarnated, I would like to return as a deadly virus, to contribute something to solving overpopulation" [5]. How much do you have to hate humanity to say such a thing? It is not surprising, therefore, that one of the main goals of the "great zeroing" is precisely downsizing the human population.

On October 18, 2019, the Johns Hopkins Center for Health Security, together with the World Economic Forum, and the Bill & Melinda Gates Foundation, held a pandemic exercise called Event 201 [6]. Business, government, and medical representatives discussed what will be needed in the event of a coronavirus pandemic, which will spread from bats to humans. It was supposed that 65 mln people would die from the infection over 18 months. The pandemic would continue until an effective vaccine is invented or the number of recovered individuals reaches 80–90 %. At the same time, the world economy will collapse by 11 %.

Information about this if publicly available, one can easily find a script, videos from the scene, final recommendations, and much more. Although the exercise was held several months before the outbreak of the real epidemic, the description of the situation coincides in many respects with what soon happened in reality. The assertion that the exercise was a rehearsal for the COVID-19 pandemic was later refuted by an "esteemed" validity check expert, the British organization FullFact. It is noteworthy that among the founders of FullFact are such companies as Facebook, Google, and the Open Society Foundations of George Soros. It is also interesting that the same platform is credited with refuting a whole series of scandalous news stories, directly or indirectly related to the pandemic, depopulation, and the role of the global elites in them.

These facts include a widely circulated online quote dated 2009 and attributed to former US Secretary of State Henry Kissinger [7]: "Once the herd accepts mandatory forcible vaccination, it's game over! They will accept anything – forcible blood or organ donation – for the "greater good." We can genetically modify children and sterilize them – for the "greater good". Control sheep minds and you control the herd. Vaccine makers stand to make billions, and many of you in this room today are investors... It's a big win-win. We thin out the herd and the herd pays us for providing extermination services. Now, what's for lunch, huh?" The same Kissinger in 1974 prepared a secret report (Memorandum 200) [8], which said that population growth in the least developed countries is a concern to US national security, and therefore it was proposed to give paramount importance to ensuring birth control and downsizing the human population. This document has formed the basis of the official policy of the United States since 1975. The report was declassified in the early 1990s.

The "medical mafia" Big Pharma for 20 years has been pursuing its goal – to create sustainable demand for its products within the framework of the new world medical order, in which a person is just a subject for experiments, something like a guinea pig. A vaccine is most suitable for this – the demand for it does not depend on market conditions. To do this, you just need to scare all of humanity, all 7.9 bln people: "Get vaccinated! Or you will die." And the demand is secured for many years, necessitating the pandemic and a constantly mutating virus, combating which will require more and more vaccines. The coronavirus fits perfectly into this scenario and it is obvious that a respective order was placed.

The prices of the vaccines that have become indispensable can be raised over time, providing long-term profits for the owners of the WHO, which has become not a defender of the health of the world population, but an effective tool for extracting profit from each of us within the framework of another anti-human program "Bio-digital Convergence", which is being developed and successfully implemented by the global elites in the framework of the "5D" program of gradual transformation of people into convergent cyborgs.

The problems of exceeding the limits of growth and overpopulation of the planet, presented by globalists since the 1970s as the main ones for humanity, are a smokescreen behind which they hide other real problems, namely, the problems of the limits of growth of capitalist production and the limits of its human capacity.

Capitalism is a system in which the few thrive at the expense of the many; the center is enriched by using the resources of the periphery. The basis of the future post-capitalist system is that it will not be for everyone either. This "brave future" is intended (which is carefully hidden) only for the "brilliant million", next to which the "golden billion" of digitized indentured servants – bio-digital convergents – will "subsist" while serving. This is on the one hand.

On the other hand, the automation of production leads to the fact that the labor needs for capitalism come down to rather low figures. Those involved in production are useful. They get paid for their work. They are also consumers. But the remaining several billion are something like annoying parasites that need to somehow, more or less, be alimented, and who, on top of all, pose a real threat to the system: if there's anything, they can rebel at any time.

The more population there is that has to be fed by the capitalist system, the more unstable it becomes. This is what the Marxists called the main contradiction of capitalism: the contradiction between the social nature of the production process and the private capitalist form of appropriation of the deliverables. That is, everyone exists within the system, but only a few can live well, and the more there are those who cannot, the more likely it is that this poor majority will overthrow and destroy the rich minority.

That is why when the global elites talk about overpopulation, they are not at all concerned about the depletion of the planet resources – in fact, they know that there are technologies today that may solve this multicomponent problem. This is how they take care of the preservation of their wealth and dominant position. This is the real meaning of "sustainable development" for them. They play with concepts to achieve their real goals. When it comes to the limits of growth for capitalism, they talk about the limits of growth in general and find ways how, by such manners, to achieve their goals, and also make money on this. This is their black magic. This is the plan of the global elites.

Therefore, a "new reality" is systematically being formed with a "new serf" – a human-like creature without properties who is easy to control and manipulate, at the level of animal reflexes, namely: asexual and soulless, without historical memory and without identity, without conscience and without morality, without a family and without children, without the meaning of life and without goal-setting (except for the sense of consumption, and not so much real as virtual and emotional).

One should not see in these plans any sort of plots and conspiracy theories. There is no conspiracy. Global elites, by masking our faces, the faces of billions of people around the world, unmasked theirs. They do not hide their intentions, they talk about it openly. Anyone can see for themselves. One has only to set a goal and spend a little time. For example, you can read the book "COVID-19: The Great Reset", written by Klaus Schwab [9] – one of the ideologists of globalists and permanent head of the World Economic Forum in Davos. Below are just a few quotes from it.

"The world will no longer be the same, capitalism will take on a different form, we will have completely new types of property in addition to private and public. The largest multinational companies will take on more social responsibility, they will take an active part in public life."

"Governments must also adapt to the fact that power is... shifting from state to non-state actors, and... to loose networks... Increasingly, governments will be seen as public-service centers."

"The greater population growth is, the higher the risk of new epidemics."

"If both democracy and globalization expand, there is no place for the nation state."

"The containment of the coronavirus pandemic will necessitate a global surveillance network."

And so on... In this book, you can find confirmation of everything that has been said above. And, for example, the UK Prime Minister, Charles, Prince of Wales, the President of the United States [10], and others do not hesitate to declare their consent with Schwab's talking points. Obviously, the heads of multinational corporations will also not object to such a program, which clearly expresses their interests.

In support of the above, we can refer to a detailed analysis of the utter futility of the socio-economic vector along which our civilization is developing, led by "deep power", as conducted in numerous works and speeches in the field of economics, nature management, ecology, sociology, and politics of such independent researchers as M. Khazin, V. Katasonov, I. Shnurenko, O. Chetverikova, A. Dugin, A. Fursov, S. Pereslegin, and others [7, 11].

The developers of the Great Reset program actually plan to zero out the technocratic vector of human development, formed over many previous millennia, as well as to zero out the human technogenic civilization itself – the one we know and form part of. Beneficiaries of capitalism, whose crisis as a system by its socio-economic nature has taken place over the past several decades, are trying to camouflage it as the crisis of humanity – the planet wide technogenic society created in the era of capitalism.

The author of this study fully understands and plainly sees that the road to the planetary civilizational hell is paved with good intentions of the globalists.

Therefore, we have a completely different plan aimed at:

1) sustainable development of the terrestrial technogenic civilization without reducing the population of the space home named Planet Earth, being aware that the cradle of humanity can easily, with no effort, "nourish and maintain" 10 bln people (and, if necessary, many times more) in the intellectual logic of *Homo sapiens*: "Go ahead with intellectual and spiritual development and perfection", because any person, unlike the machine he invented, including artificial intelligence, has spirituality, sociality, and collective identity;

2) solution of all global problems of our age with the transformation of the planet into a blooming garden in the biological (materialistic) logic of *Homo sapiens*: "Back to Live Nature" – to the origins of living matter that makes up its material body and immaterial soul, including the brain – the basis of its intellectuality and spirituality;

3) accelerated industrialization (the basic value of our technogenic civilization) with the reboot of the engineering vector of human development to a fundamentally new paradigm: "Earth is for life. Space is for industry". For which it is necessary to realize the imminence, and inevitability of the transformation of the local terrestrial civilization into the "Space" category, which is possible only with the use of fundamentally new geocosmic technologies: engineering, social, and spiritual.

At the same time, all of us who do not belong to the "brilliant million" need to make it before the civilizational point of no return, which with a 100 % probability over time (as soon as in the next 10–20–30 years) may end up in a completely different stage for the Earth's human civilization: "Welcome to a digitized, primeval, semi-bestial past".

The Ability to Transform the Existing System Without Reversing

It is quite possible to transform the capitalist system without violating the existing disposition of forces and without shocks. To do so, one won't have to abandon the achievements of civilization and the technological, i.e., industrial, vector of development that our ancestors chose. This can also be done, as in the scenario proposed by the globalists, with the help of engineering technologies. But not digital, not nature-like, rather natural biospheric technologies. Like with the program promoted by the globalists, the capitalists themselves will only benefit here. The only difference is that the rest of the future humanity (about 10 bln human individuals) will also benefit, being in the heavenly garden, spread all over the planet, and not in a digital concentration camp. It is even more important that this will help not only to preserve our common home – the Earth's biosphere but also to improve its health. Such technologies exist, all of them have been known for a long time [1, 2].

If capitalism so much needs the constant expansion of sales markets, this can be done without destroying nation states and unleashing wars, when everything needs to be built anew on the ruins (causing an increase in demand for the created products). It is possible to grow both in quality and quantity, creating new markets through the development of new technologies and respective sectors of the economy. This can be compared, for example, with what happened in the United States during the years railways and highways were built.

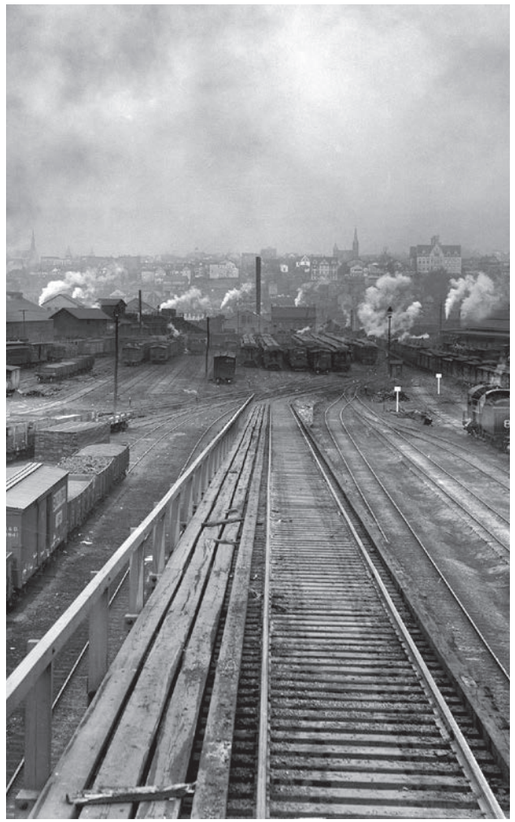
In just 10 years from 1880 to 1890, the Americans built 117,000 km of railways, which is associated with the first economic miracle of the New World. In the 20th century, cars entered mass production and more than 6 mln km of highways were constructed, which created a powerful industry, built a "single-family-home America", and created millions of new jobs, which ultimately contributed to a significant increase in gross domestic product (GDP).

Railways and highways are new technology. But that was then. Why is this impossible now? The answer is very simple. Exactly such roads and just such cars and in such quantity are no longer needed. They have oversaturated the market.

Roughly the same thing is happening in other areas, which is the root of the reasons for the planned civilizational downshifting, in which there appears to be only one possible way out. Hence, we need new engineering technologies. The ones that will improve our real material world, instead of providing an exodus from it into virtual digital slavery, absolutely alien to humans as material biological beings.

Digital products, against the backdrop of physical ones, look more attractive for the manufacturer, as they have much more headroom for growth. For example, we do not need a new car every six months, as it will not be significantly better than the previous one. But we may want to change our gadget every six months and buy new software every month, since these products can significantly surpass their predecessors. All that is left for the corporations is just aptly prompting what to wish for each one of us in the endless world of virtual opportunities – flying to Alpha Centauri, growing wings, or travelling to the era of dinosaurs.

Digital corporations can time and again awaken desires and emotions in individuals and sell them corresponding means toward these ends. Though, in fact, it's not about the desires coming true, but only about their virtual compensation. Moreover, the escape into the virtual world will lead to degradation of the real material world, built by civilization,



and the person himself (as a real-life biological subject). But, given the plans outlined above, this does not frighten anyone. On the contrary, we are urged forward. First, you don't go to the office, working remotely, then you stop needing other people, family, and don't feel the need to travel. In the end, you just die without giving offspring.

Resetting the system through its digitalization is a blind alley, since we, humans, are still biological creatures made of flesh and blood. And besides, it's not about a real reset. Since the 1970s, from the report of the Club of Rome, what the global elites have proposed is not a reset of civilization, but an arrest to its development, rigid rationing, in general, and backsliding into the digital Middle Ages. Although, a reset is possible. But not through the escape into the virtual world, but through a return to Live Nature – through natural technologies that are friendly to the Earth's biosphere. Such a reset can be carried out in two directions, which will run parallel to each other.

First direction. The use of innovative biosphere technologies in residential, transport, and industrial infrastructure, in power industry and agriculture; using all the capacities and capabilities of the capitalist production system. This will secure significant economic growth and will enable massive introduction of these biosphere technologies on a planetary scale.

Second direction. The transition to a new post-capitalist system, in which the subjects of economic activity and cultural life are small communities, numbering several thousand people, united at their place of residence (in pedestrian cluster-villages) within the framework of a single global transport and infrastructure system of linear cities.

The proposed biosphere technologies and the new system of socio-economic coordinates that may arise on their basis will be further described in detail. It is very important that the proposed model is applicable both on a scale of each individual country and the world as a whole. The implementation of the proposed solutions has a great investment potential and can become an impetus for the development of any national economy. In the future, this will significantly improve the standard of living of all people on the planet – without limitation on the size of human population and without damage to the environment.

Biosphere Technologies, a New Way of Life, and a New Socio-Economic System

As already mentioned, digital technologies are not self-sufficient. The basis of any economic system is agriculture and power industry, which are vital. What do modern experts offer in these industries? Genetically modified foods and artificial meat that are hazardous to human health. And the transition to renewable energy sources. The first point is quite clear: eating such products is simply harmful and even dangerous to health. The second is also obvious: the transition to renewable energy sources without large-scale space exploration and removal of the environmentally harmful part of the Earth's industry therein is only possible if the world energy consumption becomes significantly reduced (which is proposed as part of deindustrialization and decarbonization followed by depopulation, including through desocialization). That is, here we see a complete conformity of particular points of the "5D" program with the general vision that we have already analyzed in considerable detail.

Is there an alternative? Yes, there is. This is biosphere agriculture and ecologically clean relict solar bioenergy (RSBE).

1. Agriculture must be localized in places where people live, within walking distance, making it highly productive on living fertile humus, completely natural and organic – without the use of chemical fertilizers, pesticides, and genetic modification. Food will be produced here, in the pedestrian clusters of linear cities, and all its waste, including sewage drains, will be converted here into living high-fertile humus. New food will grow on this humus here in the cluster, which is in keeping with the natural circulation of living matter in the biosphere. This will be discussed in more detail below.

2. Energy stored in brown coals and oil shales is relict solar energy received from our luminary by living organisms that lived on the planet more than 100 mln years ago. Therefore, oil shales and coals (which have the same sets of macro-, micro- and ultramicroelements as ancient organisms, when the environment was not polluted with industrial waste) can be used not so much to generate electrical and thermal energy, as to obtain relict living humus – the basis of the fertility of any soil. This will be discussed in more detail below.

3. Residential and industrial infrastructure should be located in linear cities, which will make it possible to effectively condition not only already developed lands but remote and hard-to-reach territories (for example, mountains or sea shelf, taiga or jungle, desert or tundra), thereby solving the problems caused by widespread urbanization. Gradually, more and more people will want to settle in such places, preferring them for a more comfortable, more dignified, and happier life, instead of wasting it away in pursuit of profit in the concrete and asphalt jungles of megacities. In fact, the same as before will happen, when people began to move from villages to cities en masse, only this migration will take place in the opposite direction. This will be discussed in more detail below.

4. The allure of linear cities for investors and consumers will be secured by more comfortable living conditions therein, as well as transport accessibility with significant costs saved on the construction and operation of all residential, industrial, transport, and social infrastructure. Should, for example, the need arises to get to an existing megacity, this can be done for an acceptable amount of time and cost, even if the cluster of residence is hundreds of kilometers away. See below for detailed substantiations about this assertion and the advantages of string transport for linear cities.

The implementation of these four comprehensive biosphere-friendly solutions will ensure the recovery of the global economy.

Humus produced at solar relict biofuel power plants is one of the most demanded goods in the world today. This is because the fertile soil on the planet is degraded everywhere due to improper use. Setting up mass production of biohumus from brown coals and shales would enable exporting this highly profitable product all over the world, making a profit even higher than that of oil suppliers today. Moreover, the need for biospheric humus will be much higher than the current need for anti-biospheric oil.

Switching agriculture to living humus, enriched with associations of useful soil microorganisms (instead of dead chemical fertilizers) will increase the yield and quality of agricultural products – it will all become only organic. In turn, this will be an investment in the health of the world population and in human potential. It is very important that such products are obtained within walking distance and by the same producers who will then consume these food products – it is difficult to imagine a better quality control of agricultural products, being the basis of our health. In addition, it will ensure food security for all residents of the linear city.

The creation of a new transport and infrastructure industry based on Unitsky String Transport (uST) technologies will provide orders for enterprises engaged in construction, mechanical engineering, manufacture of construction materials, metallurgy, software development, electronics, power industry, and so on.

The construction of linear cities will stimulate the real estate market and allow developing remote territories. At the same time, a significant share of the costs of all of the above (power industry, agriculture, transport, housing) can be borne by end consumers – future residents of linear cities, since all these elements are part of the urban infrastructure. Like, for example, an elevator in the building, a playground in the backyard, or a car park are all parts of a residential complex, the cost of which is included in the price of an apartment bought by an individual.

The state can stimulate demand by launching various programs, including mortgages. Then, as linear cities are constructed and people move there, the entire socio-economic system will change. To understand what will happen, one need to look at the way of life in the new linear settlements, which will be discussed in more detail below.

Since the basis of the plans for the "great zeroing" is allegedly the achievement of the growth limits of civilization and the economic capacity of the planet, along with the scarcity of terrestrial resources and ensuing global problems (with the paranoid restrictions imposed on humankind in everything and everywhere, including in the very intelligence of *Homo sapiens*) the main part of the comprehensive research undertaken in this work is therefore aimed at dispelling these pseudoscientific myths.

Criteria for the Limits of the Economic Capacity of the Biosphere

The limits of the economic capacity of the Earth's biosphere can be regarded from various positions.

1. Biosphere is a living matter (about a trillion species of unique, inimitable, and very complex, from an engineering point of view, living organisms [12]), created by nature on planet Earth over the past 3.5 bln years of the evolution of the Universe;

2. Terrestrial technogenic human civilization is a megasociety of 7.9 bln individuals, created by one of the types of living organisms (*Homo sapiens*) in the biosphere of planet Earth over 2 mln years of development of engineering (industrial) technologies;

3. Technosphere (global industry) is a dead matter created mainly over the past two centuries (during the period after the world population reached 1 bln people) by a technogenic civilization in the form of millions of primitive engineering technologies, each of which (for example, an airplane or a smartphone) in terms of the complexity of the engineering solutions incorporated therein is millions of times inferior to the simplest living being – a microorganism [13].

It should be noted that both modern humankind and the artificial intelligence it is creating are intermediate (not final) biospheric products (between the animal past and the civilizational space future) of the technogenic vector of the development of the Earth's human population, therefore, neither of them will be able to sustainably exist and, moreover, develop without the engineering technologies that gave rise to them.

The sustainable development of our civilization, including in the distant future, is possible only as a result of the creation of new socio-industrial technologies friendly to the biosphere, and not through deindustrialization and total closing-up (in fact, zeroing out) of existing industrial technologies.

We are not a civilization of dolphins, which, having a very high intelligence and a shared language (even more complex than that of humans) are nevertheless a population of animals that are completely dependent on the environment, since they have neither science, nor art, nor civilizational society and spirituality, nor engineering technologies, including industrial ones.

All existing industrial technologies hostile to the biosphere must either be reconstructed into "biospheric" technologies, or, if this is impossible, removed from the planet into a dead environment – near space.

The concept of "economic capacity of the biosphere" is an unacceptable criterion for an objective analysis, since modern human economic activity is based on existing industrial technologies, for which the main impetus for development and progress over the past few centuries has been profit-making and growing GDP per capita in intangible (digital) money terms.

Therefore, a system analysis must be performed on the basis of physical (not virtual monetary) characteristics and not by transferring modern parasitic and large-scale industrial technologies opposed to Live Nature in the future, but by relying on natural biosphere technologies, already known today, but not widely used. The main thing is that these technologies should befriend real Live Nature and the biosphere as a whole, instead of the virtual digital economy of artificial intelligence that went mad, where neither we nor Live Nature are needed – we are unwanted there.

The analysis must be performed on the basis of the main physical criteria: matter, energy, and information, which are the main resources both for the biosphere, whose biological component is humanity, and for the technosphere, whose intellectual (informational) part is also humanity, but as a planetary society – technogenic civilization. The main matter here is:

1) for humanity:

- living fertile soil based on natural humus;
- organic (natural) foodstuffs (grown on living fertile humus, containing almost the entire periodic table) as a source of energy and raw materials for the construction of any cell in our body;
- clean, slightly mineralized natural drinking water, also containing almost the entire periodic table (for example, spring water contains about a thousand dissolved minerals, while distilled water, which does not contain any minerals at all, is highly dangerous to human health);
- clean atmospheric air containing life-giving oxygen (on average 20.9 % by volume, 23.1 % by mass), which is produced and quantitatively regulated by living terrestrial organisms;
- every square meter of the Earth's surface and every cubic meter of soil and water is a living space that a long time ago, billions of years, was all over the place occupied by the real masters of the planet – living organisms (mainly microorganisms) with which our multicellular ancestors, including the primogenitor, learned (or rather evolutionarily adapted) how to coexist peacefully many millions of years ago;

2) for the industry:

- mineral raw materials (almost the entire periodic table);
- energy (fuel) resources;
- clean atmospheric air, from which the industry needs, basically, only oxygen (for example, for fuel combustion);
- process water, including distilled water or containing special process additives, as a rule, life-threatening;
- square meters of the planet surface and cubic meters of soil and water – technological space taken away from the Earth's life and then polluted with dead and alien man-made waste that is dangerous for the living biosphere.

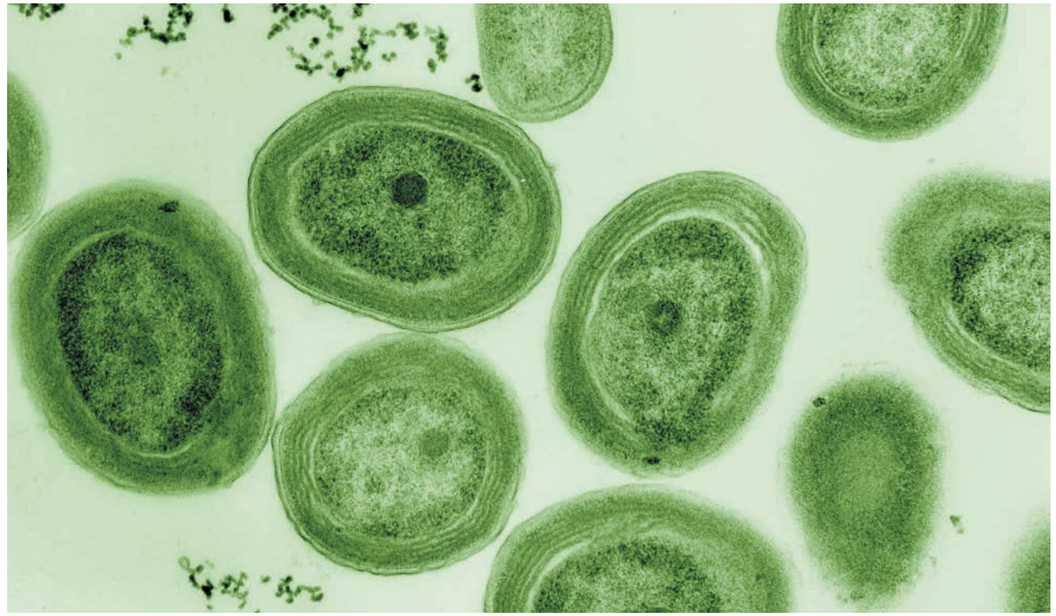
Since humanity has nothing to do with the creation of the terrestrial biosphere (it only came to the notice with its attempts to destroy it), the biosphere itself is not viewed in this study as a subject of system analysis.

Natural Resources and Their Criteria

The modern living biosphere of Earth is created by billions of species of living beings on the inherently dead planet, the third in a row from a star of the "yellow dwarf" category, on the outskirts of an unremarkable medium-sized spiral galaxy. Life may have arisen by chance from a random set of several dozen chemical elements due to a random combination of several dozen favorable physico-chemical and natural climatic conditions. The probability of the emergence of the basis of such a life – super complex in terms of the structure and functioning of a living cell – is equal to zero (a more accurate mathematical probability: 10^{100} times less than the ratio 1 : 10^{100}), but it did begin.

The evolution of the terrestrial biosphere took about 3.5 bln years, it is regulated by life, governed by life, and optimized by the entire planetary life, and not by any one kind of living organisms. First living creatures that inhabited the new planet were blue-green algae (protozoal cyanobacteria).

The dead technosphere was created according to completely different physical patterns – it is completely built around engineering technologies by only one of the types of living organisms endowed with intelligence – man. Who also regulates, governs, and optimizes it. The first complex engineering technologies laid in the foundation of the technological development of the Earth's human civilization



are chipped stone tools, created about 3.5 mln years ago. But more important technological inventions are techniques of making a fire and cooking food on fire by burning one biospheric product (tree) in another biospheric product –oxygen from air (appeared about 2 mln years ago).

The biosphere and technosphere created on different – antagonistic – principles, occupied the same niche in space and in time on our planet. There is a struggle between them for resources – life (biosphere) and technological (technosphere). Therefore, it is necessary to distinguish between:

- living matter and dead matter;
- resources for life and resources for engineering technology;
- energy for life and energy for industry;
- space (environment) for life and space (environment) for technological processes;
- safety for living organisms and safety for industrial technologies;
- information for the continuation and development of life (material DNA molecules and genes, where both the carriers themselves – the atoms of chemical elements of almost the entire periodic table – are important and their spatial combinations, i.e., information itself) and information for engineering technologies (virtual numbers recorded on physical media, where the media have no significance, and only the numbers themselves matter).

Both living beings (microorganisms, plants, and animals, including humans) and industrial "beings" (engineering technologies, equipment, buildings, structures, etc.) are open systems. They exchange matter, energy, and information with the environment on the same basic principles: at the point of entry to the system they have resources, at the point of exit from the system – a product (service) and waste generated as a result of metabolic processes and extraction of a product or service useful for the humans from the source raw materials (for example, melted steel for a blast furnace, a provided transport service for a car, milk and meat for a cow).

At the same time, products useful to humans and the resulting waste (both industrial and organic) end up in the same environment from which the source raw materials were taken (for example, raw materials are ore, coal, and aerial oxygen for a blast furnace; grass, water, and aerial oxygen for a cow), i.e., in the biosphere of the planet. Therefore, any industrial technology, no matter how green and zero waste it may be, will inevitably pollute the living biosphere with dead products alien to it and dead waste. The desire to create waste-free engineering technologies is equivalent to attempts to "improve", for example, a cow (and it does not matter,

"with carrot or stick"), so that it produces only milk and meat, without generating any manure, urine, methane, CO_2, or any other waste.

Life has changed and harmoniously adapted the inherently dead planet for itself, making it alive; the industry will inevitably change the living planet for itself, making it dead – it's only a matter of time. The only way out is to move the terrestrial industry (technosphere) outside the terrestrial life, i.e., the biosphere. And there is only one place close to our Earth's civilization for processing dead raw materials into dead products without negative impact and pollution of the living Earth's biosphere – this is near space, the dead space surrounding the planet.

Biosphere Resources

The house in which humankind lives (not the entire planet Earth, but only a very small part of it in terms of size and mass) is the biosphere of the planet. And not even the entire biosphere, but only the uppermost part of the Earth's crust and the lowermost part of the Earth's atmosphere (from the roots of trees to their tops), which has a relative thickness of about 1/100,000 of the planet diameter. In fact, it is the thinnest living film, the delicate "skin of the planet", where practically all the Earth life is located and where humans have placed the bulk of the Earth's industry (except for planes, rockets, and submarines that are in motion performing transport work). Both terrestrial life and terrestrial industry use the main types of resources from this particular part of the biosphere.

At the same time, all of humanity, like one large family of almost 8 bln individuals, is "registered" not even in a house, but in one shared and very large "communal room" – the biosphere, which has no windows, doors, or partition walls, where Live Nature originally "registered" billions of other rightful families – species of living organisms.

The composition of the cells of any living organism includes 86 chemical elements of the Periodic System – macro-, micro- and ultramicroelements, 25 of which are required for the normal functioning of the organism, and 18 of them are absolutely indispensable, usually as part of complex organic compounds acquired with food [14].

Water is the most important biospheric mineral resource for the birth and existence of any living Earth organism. H_2O makes up, on average, about 75 % of the mass of any living cell, therefore, the main chemical element of the cell by weight is aqueous oxygen, and as the dry residue, after evaporation of water, it is carbon, about 60 % by weight.

Land plants, which account for 98 % of all Earth's biomass take this basic chemical element required for building cells from the carbon dioxide contained in the atmospheric air. Therefore, atmospheric CO_2 is also the most important biospheric mineral resource.

Each living organism, as noted above, is an open system and, accordingly, a participant in biospheric metabolism. It consumes food, water, air from the biosphere and discharges its biowaste back into soil, water, and air. Organic waste, in turn, becomes food along the chain from some types of microorganisms (through flora and fauna) to other types of microorganisms. Therefore, the simplest forms of life are the beginning of food chains and they also end up with them, therefore, communities of microorganisms (primarily soil ones) are the basis of all biospheric processes and, in fact, the main creators of the Earth's biosphere.

Oxygen (and, as a derivative, the ozone layer) has also become an intermediate waste of biospheric metabolic processes; it has become an indispensable atmospheric mineral resource for most contemporary species of organisms (primarily for fauna, including humans).

Generations of sponges, myriads of myriads of bacteria and algae are the real creators of the modern Earth's crust, including the accumulated reserves of sediment, chalk, iron, and even gold and diamonds. Almost all organisms need phosphorus, calcium, and, of course, carbon. Creation of a limestone skeleton (as in corals or ancient archaeocyates) occurs with the release of carbon dioxide, so the greenhouse effect was a by-product of the construction of reefs in ancient times.

For example, coccolithophorids absorb not only calcium from water but also sulfur dissolved in it. It is required for the synthesis of organic compounds that increase the buoyancy of algae and allow them to stay close to an illuminated surface. When these cells die off, the organic matter disintegrates, and the volatile sulfur compounds evaporate along with the water, serving as a premise for the formation of clouds in the planet atmosphere. One liter of seawater can contain up to 200 mln coccolithophorids, and each year these unicellular organisms diligently supply up to 15.5 mln tons of sulfur to the atmosphere – more than, for instance, all volcanoes and all terrestrial transport [15].

Even lighter continental plates were formed largely thanks to living organisms, which, by transforming volcanic rocks into other minerals, changed the tectonics of the planet – heavier oceanic plates, as they moved, began to dive under lighter continental plates. There, in the hot bowels of the planet, they melt in this natural chemical reactor at a depth of 120–180 km, forming diamonds from dead organic matter (ocean bottom sediments), which are then carried out by volcanic eruptions through kimberlite pipes to the surface of the Earth's crust.

It should also be noted that the flow of energy produced by living organisms on Earth is 30 times higher than the geological flow of energy [16].

Ultimately, living organisms, using solar energy, process dead matter of the planet into living matter, the final product of which (i.e., the final organic waste) is silt, also known as sapropel (bottom sediments of freshwater reservoirs), as well as soil humus – the basis of fertility of any living soil on the Earth's land.

All biological resources are renewable (infinite) due to the circulation of matter, energy, and information in the Earth's biosphere. Only the Sun, a source of energy, is external to the biosphere. Therefore, life on the planet will exist in one form or another for at least another 5 bln years, until our star goes out.

Thanks to the Sun and atmospheric oxygen, another irreplaceable by-product (waste) has been formed in the Earth's biosphere – the ozone layer. Without it, life on the planet (primarily on land) would be impossible due to the harsh ultraviolet radiation of our star. The ozone layer is in dynamic equilibrium and its key enemy is stratospheric aircraft and space rockets. For example, one blast-off of a heavy launch vehicle burns out a tunnel the size of France in the ozone layer and destroys about 10 mln tons of ozone, and 100 frequent launches can completely destroy it [13]. While such "ozone holes" are then gradually healed under the influence of solar radiation and the production of new ozone, the harm from them is obvious, and it is enormous.

Living Matter and Humus as a Resource

Humus in the soil is the main biospheric waste and, at the same time, is the main food resource of organic origin for flora (i.e., for about 98 % of all terrestrial biomass), containing all the chemical elements necessary for life in the form of the most complex sets of organic substances. But the main thing is different – each kilogram of fertile humus provides working space for about a trillion toilers, included in the most complex symbiosis of several tens of thousands of species of soil bacteria and microorganisms, without which the normal existence of biogeocenoses would be impossible.

The food chain of all terrestrial life originates in the soil. Some microorganisms accumulate insoluble humic compounds (otherwise the nearest rain would wash out all the food from the soil), others convert them into a soluble form while feeding and watering the plants, since they live not only in the soil but also in the roots, and in the aerial part of plants. At the same time, they have a rather narrow area of expertise, since they produce thousands of various organic substances, which include more than 80 chemical elements of the periodic table, without which the existence of any multicellular organisms, including humans, is impossible.

In essence, the living fertile humus of Earth's soils is not only the main biosphere resource but also the main component of the global immune system – it feeds, waters, and heals the biosphere and, consequently, us, the people, also by means of healthy, wholesome, and salubrious food, grown on this soil. The health of flora and fauna, including humans, depends on the health of living fertile soils, which are almost everywhere destroyed by tillage, chemical fertilizers, pesticides, and industrial pollution. In particular, it is the weakened immune system of the biosphere and, accordingly, of humans that are the main causes of the emergence and spread of epidemics and pandemics.

Therefore, humus is an irreplaceable biosphere resource and the main biosphere food, since some types of microorganisms process a variety of dead organic matter into insoluble humus, accumulating it in the soil, while others convert it into a soluble form and feed the plants.

In the Earth's biosphere, about 200 bln tons of dry organic matter (about 1 tln tons on a live weight basis) are produced annually in the process of photosynthesis, and about the same amount dies and disintegrates [17]. If only 1 % of this annually dying organic matter (about 10 bln tons in live weight) is converted into food by transforming it into living fertile humus (inter alia, in the stomachs of cows) and agricultural products are grown on it, then these organic products (without the use of GMOs and chemicals) can be used to feed the entire future Earth's population of 10 bln people, which is proven below.

In the last 500 mln years of active photosynthesis alone (although life on Earth originated more than 3 bln years ago) the biosphere produced 200,000,000,000 t/year × × 500,000,000 years = 10^{20} tons (or 100 mln trillion tons) of dry organic matter. If this organic matter had not then been involved in the biospheric circulation of living matter, then at a density of 1 t/m^3 (like coal), the layer of this organic matter on the planet (including water areas) would have had a thickness of about 200 km. This, for example, is six times the average thickness of the Earth's crust, so the powerful transformative force of life is evident, inter alia in the geology of the formation of the modern Earth's crust and continents.

Should we evaluate this resource in money, the minimum cost of delivered biosphere products (dry organic matter and the derived humus), at a minimum price of 100 USD/t, will be (for the past 500 mln years): 10^{20} tons × 100 USD/t = = 10^{22} USD (or 10 bln trillion USD). This is the minimum "cost" of the organic component of the Earth's biosphere, including reserves of humus, sapropel, shale, coal, oil, natural gas, etc.

Atmospheric Oxygen as a Resource

The organic matter of the biosphere contains 16 tln tons of oxygen, and the upper layer of the ocean contains 8 tln tons. The atmosphere contains – 1.4 × 10^{15} tons, or 1,400 tln tons (i.e., 58 times more), including about 3 bln tons (0.00021 %) as the ozone layer. At the same time, the atmospheric cycle of oxygen is 4,500 years [18].

The annual photosynthesis of oxygen by the biosphere is more than 310 bln tons. Of these, there is annually expenditure as a resource:

- for biospheric needs: aerobic respiration – 230 bln tons, microbial oxidation (decay) – 51 bln tons;
- for industrial needs ("anthropogenic respiration"): burning fossil fuels and nitrogen fixation in the production of mineral fertilizers – 12 bln tons (or 4 % of the oxygen produced on the planet);
- for other oxygen losses – photochemical oxidation, chemical erosion, nitrogen fixation with lightnings, oxidation of volcanic gases, etc. – amount to about 20 bln tons, which, for example, significantly exceeds its expenditure for the entire Earth's industry.

Over the past 2.5 bln years of biosphere evolution, oxygen photosynthesis has produced more than 5 × 10^{20} tons of oxygen (or 500 mln trillion tons). The oxygen released during photosynthesis radically changed our planet, and not only the atmosphere but also the lithosphere – it was almost immediately spent on the oxidation of rocks, mineral compounds dissolved in the oceans, and gases of the primary atmosphere. For example, most modern iron ore deposits are the result of oxidation over billions of years of iron compounds dissolved in water and their sedimentation.

Based on the efficiency of the biosphere, an increase in the productivity of photosynthesis by only 5 % will increase the production of atmospheric oxygen by 15 bln tons per year, which more than outweighs its expenditure for "anthropogenic respiration". In turn, an increase in plant productivity can be achieved by increasing the content of anthropogenic carbon dioxide in the atmosphere, including as a result of the operation of relict solar biofuel power plants in linear cities [2].

Water as a Resource

The total amount of water on the planet is 1.39 × 10^{18} tons (or 1.39 mln trillion tons), which is 275 times the mass of the atmosphere, but is only 1/4,000 of the mass of Earth [19]. Salty ocean waters make up 96.4 % of the volume of the hydrosphere, fresh waters: glaciers – 1.86 %, underground – 1.68 %, surface water on land – 0.02 %.

The mass of water vapor in the atmosphere is 14 tln tons (about 0.001 % of the mass of the hydrosphere, or 0.27 % of the mass of the atmosphere), however, the importance of water vapor for life on the planet is difficult to overestimate, because the atmosphere is the main desalinator of salty sea water. Analysis shows that 450 tln tons of water evaporate from the surface of the oceans per year – a layer 1.25 m thick [20]. Another 71 tln tons of water enters the atmosphere, evaporating from the surface of the land. Simultaneously, the same volume precipitates on the planet surface (on average 1,020 mm per year). That is why the water level in the oceans is stable and practically does not change due to its evaporation.

The colossal amount of thermal work that has until now been carried out by our nearest star on the planet staggers the imagination. Over 3.5 bln years (since the appearance of life), the Sun has evaporated such an amount of water on Earth, which would have an ocean with an area equal to the surface area of the planet and a depth of more than 3 mln km (!), which, for example, is eight times greater than the distance from Earth to the Moon.

No less grandiose is the scale of the transformative power of living organisms for the evolution of our planet, including for its water balance, which can be understood from the following example. If all the oxygen newly produced by living organisms did not participate in the biospheric circulation, but were removed from the atmosphere and expended only for the oxidation of hydrogen and the production of water, then a layer of liquid 0.5 mm thick would appear on Earth in a year. For 2.5 bln years of active photosynthesis, this would form an ocean covering the entire Earth with a depth of more than a thousand kilometers (!).

Therefore, it is possible that the bulk of water on our planet was not brought by comets from space, as it is generally

recognized, but was formed by oxidation of hydrogen constantly entering the atmosphere from the depths of Earth due to degassing of the Earth's core [21]. Evidently, the same processes are happening today, therefore, not only ice melting and "global warming" are involved in the rise in the ocean level today but also the additional generation of water by the Earth's biosphere.

Humanity annually consumes about 11 tln tons of water, of which: from river runoff for irrigation – about 6 tln tons, for industrial purposes – 4.1 tln tons, and everyday necessities – 0.9 tln tons, which is only 2.1 % of the world precipitation. Therefore, all humankind's demand for fresh water can be met not only from precipitation (rain and snow) but also by additional condensation of water vapor from the air at the place of its consumption (to reduce the cost of water transportation). This can be implemented in linear cities, described in detail below, where there are no large consumers (neither agricultural, nor industrial, nor domestic), as it was earlier in rural areas, when all water needs were met from small sources – wells, springs, streams, and shallow boreholes.

Technological Resources

The main resources for the industry are mineral raw materials (ore, stone, sand, etc.), energy raw materials (coal, oil, gas, etc.), and various substances taken from the environment for the implementation of technological processes:

- aerial oxygen, as the most accessible oxidizer in the combustion of fuel in internal combustion engines of cars, airplanes, and ships, as well as in thermal power plants, boiler houses, blast furnaces, etc. Depending on the type of fuel and the technology of its combustion, one requires 2–8 times more oxygen by weight than the fuel itself (for example, two times for coal, eight times for hydrogen), and 10–40 times more air respectively;
- water, as the most accessible universal solvent and the main liquid medium for most chemical and technological processes.

The extraction of non-renewable minerals and building materials on the planet has already exceeded 60 bln tons per year (about 8 tons per inhabitant) and continues to grow. Of these, there are more than 10 bln tons of ore (including iron – 2.4 bln tons and copper – about 4 bln tons). Cement production reached 5 bln tons per year, concrete – exceeded 30 bln tons [2].

Energy raw materials are now mined in the amount of more than 15 bln tons annually (coal – about 8 bln tons, oil – 4.5 bln tons, and natural gas, including shale, – more than 3 bln tons). The fuel is then burned using air, which contains its oxidizing agent – oxygen. At the same time, the total rated capacity of energy equipment on the planet using fossil fuels, including thermal power plants, boiler houses, and all types of vehicles (road, rail, aviation, and sea transport, rockets, etc.) exceeded 100 bln kW. This equipment is extremely inefficient, has overcapacity and is used on average by 10–15 % (cars, for instance, are not loaded both in terms of power and time).

The extraction of construction sand on the planet has exceeded 11 bln tons; gravel (crushed stone), including that for the manufacture of concrete, – 20 bln tons. The scope of earthworks (with the displacement of soil over tens or even hundreds of kilometers) during the construction of roads, factories, power plants, buildings, structures, and other infrastructure facilities (mainly in cities) exceeded 30 bln tons per year.

According to the author's estimates, the scope of strip mining and remediation work in the extraction of mineral raw materials reached 300 bln tons per year (with an average overburden ratio equal to 5 tons for each ton of mined mineral raw materials).

Therefore, about 400 bln tons of minerals are mined, processed, and transported on the planet annually over an average distance of several tens of kilometers, of which 300 bln tons is common soil, including rocky soil, which goes to the dump (for which, in fact, the best part of fuel consumed by the equipment is spent). At the same time, certain raw materials and resources are transported using inefficient, outdated, and environmentally hazardous transport over distances exceeding 10,000 km.

On all the continents, the industry leaves a vast number of "scars" on the "Earth's skin". Most particularly, on the living fertile soil, a layer of which with an average thickness of about 40 cm is equal to only 1/30,000,000 of the size of the planet. More and more "furuncles" and "sores" appear on the thinnest "planetary skin", that is why it cannot be healthy. These are huge concrete-asphalt megacities, many kilometers of quarries, mines, and boreholes, high and extensive dumps, elongated embankments and road cuts (with a total length of more than 60 mln km – 15,000 lengths of the equator), changing the terrain, destroying soil fertility, and deteriorating their biogeocenosis and hydrology (movement of surface and ground waters). For example, the land with a size five times that of Great Britain has already been "paved over" and "buried" under railway sleepers only to build the roads on the planet [22].

The mass of annually mined and transported mineral resources in the biosphere of the planet is currently two times higher than the generation of living matter in it (about 200 bln tons of dry organic matter per year), therefore it is here that the greatest impact and influence of the technosphere on the Earth's biosphere show themselves.

Humanity must cardinally revise its attitude not only to all industrial technologies as such but also to technologies for the extraction of minerals (and not just to the volumes of their extraction, as is generally accepted). Likewise, to the construction of roads in a linear embankment, so that the volume of extracted and moved minerals on our planet is reduced by at least an order of magnitude.

The main consumer of industrial resources today, both mineral and energy, are cities that are intensively built up and expanded. In the cities there is also the main end user of the energy generated on the planet – from lighting, heating, and air conditioning of buildings and structures to fuel combustion by cars or the consumption of electric power by electric vehicles.

All technological resources are non-renewable (finite) due to the lack of circulation of substances, energy, and information in the man-made technosphere. The main reason is that it does not have a myriad of myriads of microscopic equivalent robots such as microorganisms in the Earth's biosphere, working at the atomic and molecular levels. If they were, they could, everywhere on the planet, at every point of its surface, close local trophic industrial chains, when the waste of some engineering technologies in each specific place of production of goods or services (without any additional transportation and additional costs of energy and other resources) would become raw materials for other engineering technologies and industrial resources (as well as biosphere ones), would become renewable.

Therefore, the terrestrial industry will exist until it converts all the resources it needs into industrial waste that is thrown into the biosphere. And it doesn't matter what happens earlier (the resources will run out, or the biosphere will be polluted and destroyed), in any of these scenarios any technogenic civilization (not necessarily terrestrial) has no future on its home planet – it will inevitably fade away and then die. Moreover, according to a number of forecasts, this can happen on our planet as soon as during the 21st century, if the vector of civilizational technological development is not changed and the environmentally dangerous part of the terrestrial industry is not taken into space. Only such a vector of development will give our technogenic civilization the access to the infinite resources of the Universe – mineral, energy, spatial, and technological (weightlessness, deep vacuum, technological purity, etc.) [13].

Greenhouse Gases in the Earth's Atmosphere and the Global Greenhouse Effect

The greenhouse effect on the planet is due to the presence in the surface layer of the atmosphere of polyatomic gases that are opaque to thermal radiation – water vapor, carbon dioxide, methane, ozone, nitrogen oxide, freon, etc.

Water vapor, of which there is 12.7 tln tons in the Earth's atmosphere, is the most active greenhouse gas in terms of its contribution to the rise in temperature on the planet. Its contribution to the total greenhouse effect on Earth, reaching 32 °C, is 20.2 °C (against the contribution of CO_2, which is 7.2 °C) [23].

The greenhouse effect on Earth now is on average by up to 78 % due to water vapor and only up to 22 % (i.e., 3.5 times less) – to carbon dioxide. Contributions from other gases, including methane, can be neglected whatsoever [24]. That being said, in terms of one ton of gas contained in the Earth's atmosphere, the greenhouse efficiency of one ton of carbon dioxide is only 1.5 times higher than the greenhouse effect from one ton of water vapor.

Without greenhouse gases, the average temperature on Earth would be about –18 °C, meaning that rivers and seas would always be frozen and there would be no plants on land (while today it averages about 15 °C).

Emissions of industrial water vapor (for example, from cooling towers of nuclear power plants) are not so harmless after all, because each ton of steam entering the surface layer of the atmosphere is equivalent in terms of the "greenhouse effect" to 0.67 tons of carbon dioxide. Therefore, the environmental friendliness of a nuclear power plant is an illusion not only because of problems with radiation but also due to climatic factors, since for every kilowatt-hour of electricity generated at a nuclear power plant, 3.6 kg of water vapor is released into the surface layer of the atmosphere. For example, in 2015, Russian nuclear power plants alone emitted 730 mln tons of water vapor into the atmosphere (in terms of CO_2 – about 490 mln tons of carbon dioxide [23]), which significantly exceeds greenhouse gas emissions by all Russian transport, including cars.

Additional sources of water vapor entering the planet atmosphere (in billions tons per year): evaporation from waters used for domestic needs – 180, evaporation from industrial waters – 800, from river flows for irrigation – 5,400. In total, as expressed in CO_2 (from the standpoint of the global greenhouse effect), this is more than 4,000 bln tons of carbon dioxide.

Considering that the greenhouse effect from water vapor in the atmosphere (with reference to one ton) is only 1.5 times less than CO_2, the impact of anthropogenic activities on the water vapor circulation and its contribution to the greenhouse effect is 140 times (!) greater than the carbon contribution from carbon dioxide generated by the entire Earth's industry, including transport.

Therefore, it is actually more important today for humankind to engage in the optimization of water consumption in everyday life, industry, and especially in agriculture, in order to organize a successful fight against "global warming". It is more significant than, for example, at the behest of globalists, to redirect all the civilizational efforts to the tilt at "carbonic windmills". Because it is quite obvious that the decarbonization program promoted by the globalists pursues completely different goals, including their obsession with global warming.

The fact that carbon dioxide is not the main climate-forming factor is evidenced by the entire multimillion-year-old history of the development of life on our planet. For example, 250–320 mln years ago, in the Carboniferous period, the concentration of carbon dioxide was two times lower than it is now, but the average temperature was 10 °C higher [25]. While 150–200 mln years ago the content of CO_2 was almost an order of magnitude higher than now – 0.3 %, and 400–600 mln years ago – even 0.6 % [26], while there was no global warming, on the contrary, almost the entire planet was covered with ice.

Safe Carbon Capacity of the Earth's Atmosphere

The total mass of carbon dioxide in the Earth's atmosphere today is 3.03 tln tons (about 0.038 % of the total mass of the planet atmosphere), of which 550 bln tons annually dissolve in seawater and transform into living matter as a result of photosynthesis [27]. This means that, on average, all atmospheric CO_2 participates in the carbon planetary cycle every 5–6 years.

The creation of organic matter annually consumes about 300 bln tons of carbon dioxide, i.e., about 10 % of the amount of CO_2 contained in the atmosphere [28]. Then, almost all of this mass of carbon dioxide returns back to the atmosphere and hydrosphere as a result of the oxidation of once-living organisms and their waste products.

The largest amount of free carbon dioxide in the biosphere is actually in the upper layer of the ocean – 140 tln tons, which, for example, is 46 times more than there is in the atmosphere.

It should be noted that the carbon cycle as a result of the creation of organic matter in the Earth's biosphere is completely closed. Of the total mass of organic carbon absorbed by plants annually, only an insignificant part passes into the lithosphere and leaves this cycle.

Studies have shown that the current level of carbon dioxide in the Earth's atmosphere for effective photosynthesis is 2–3 times lower than the optimal one. This, in particular, is evidenced by the data on the levels of CO_2 – in commercial greenhouses the optimal yield is cited at levels of 0.1–0.12 % or more [25]. Based on this, we can conclude that there is a shortage of carbon dioxide in the Earth's biosphere from the viewpoint of all living matter (rather than a very limited in the biosphere knowledge "globalist-man" – one of a trillion species of living organisms) of hundreds of billions, if not trillions of tons.

Increase in CO_2 concentration in the atmosphere is in fact caused not so much by industry and transport as by its return from sediments in the ocean and on land due to an increase in the average temperature on the planet (not vice versa). At the same time, it increases crop yields, promotes the growth of forests and meadow plants, as well as fish, crustaceans, mollusks, algae, and corals in the ocean.

Therefore, the current global level of industrial CO_2 emissions (about 30 bln tons per year, i.e., 1 % of its content in the atmosphere) will affect the greenhouse effect at a maximum of 1 % of the above-mentioned 22 % impact of carbon dioxide on the climate, i.e., for a total of a mere 0.22 %. This is significantly lower than the margin of error in measuring the average temperature on the planet and the average CO_2 content in the atmosphere. It is obvious that an additional greenhouse effect will manifest itself only if this industrial carbon dioxide remains liberated, instead of being bonded by green plants (or green technologies) in industrial regions or dissolved in the ocean thereafter.

Therefore, the recently vilified anthropogenic CO_2 is completely safe for the biosphere and not only is not excessive but does not even make up for the carbon deficiency in the Earth's atmosphere.

It is important to remember that the dry matter of any organism (i.e., without regard to the oxygen and hydrogen that make up the water of any living cell) is about 60 % carbon. Carbon is the main chemical element of life on Earth, including humans. The food chain for carbon begins precisely in the atmosphere, where it should be present in sufficient quantity from the viewpoint of the evolution of the living biosphere, not the dead technosphere created by human civilization, or artificial intelligence, which does not need a biosphere at all.

Energetically Safe Capacity of the Earth's Biosphere

World Energy Consumption

World energy consumption refers to the total amount of energy consumed by the civilization. It includes all the energy obtained from all energy resources and used in all industrial and consumer sectors of the world economy. World energy consumption is an important indicator of the level of development of a technogenic civilization both in the productive-economic, and the socio-political fields of its activity.

The average density of solar energy at the outer edge of the Earth's atmosphere is 1.366 kW/m^2. It has already been calculated that without this energy coming to our planet (if the Sun is "switched off"), the temperature of the atmosphere will drop to –20 °C over a week, to –73 °C over a year, and over a few years the temperature on Earth will drop to –240 °C and will remain at this level [29].

The prevailing opinion is that over the past 2,000 years, i.e., over the entire new history, when the Earth's industry appeared everywhere and started to develop intensively, solar radiation was stable, with variations within 0.2 %. Such variations in the intensity of solar radiation will amount to only 2.732 W/m^2, which, with a cross-sectional area of Earth of 130 mln km^2 (including the atmosphere), provides fluctuations in the power of external energy falling on the planet of 350 bln kW. For example, this value exceeds by 167 times the total rated capacity of all power plants in the world, equal to 2.1 bln kW (with a population of 7.8 bln people at the beginning of 2021, this amounts to only 0.27 kW of electric power per inhabitant of the planet).

We shall assume that the same fluctuations in the power of the additional (extrasolar) energy supply of the planet from the technogenic civilization will be acceptable in the future and will not lead to global environmental problems. Moreover, the power of solar energy reaching Earth is itself unstable over time due to changes in the distance to our star (from 147 mln km in January to 152 mln km in July) – such fluctuations in the course of a year reach 6.9 %, which is, for example, 34.5 times greater than the above 0.2 %. Moreover, the luminosity of our star increases by 1 % (the power of solar energy reaching Earth will increase by 1.78 tln kW) every 110 mln years due to the accelerated combustion of hydrogen. Therefore, in 4–5 bln years the Sun will go as far as turning into a red giant, expanding, and simply swallowing Earth [29].

The capacity of modern energy consumption, considering the combustion of nuclear power industry and hydrocarbons, is more than 20 bln kW (2.6 kW for each inhabitant of the planet). Then, with an increase in the future power of energy consumption per capita to 5 kW (i.e., with an annual energy consumption per capita in the amount of 43,800 kW·h), with regard to its environmental optimization, the safe capacity of terrestrial power industry is: 350,000,000,000 kW / 5 kW/person = 70,000,000,000 people of the world population.

At the same time, at least 1/2 of this energy is currently consumed by the industry itself – transport, metallurgy, chemical production, and other types of industry, including fuel for the production of agricultural products. That's why, by moving the environmentally hazardous part of the industry outside the biosphere – into near space – and optimizing the industrial technologies remaining on Earth (primarily transport and infrastructure, power, and agricultural), energetically-safe civilization capacity of the biosphere of our planet will increase at least two times, i.e., up to 140 bln people.

With a future Earth's population of 10 bln people, the power capacity that is safe for the biosphere per one inhabitant of the planet will therefore be: 350,000,000,000 kW / 10,000,000,000 people = 35 kW/person. This is, for example, 13.5 times higher than the current per capita power consumption of the entire terrestrial technogenic civilization.

Optimization of Biosphere Energy Resources

The total global biosphere reserves of shales are estimated at 650 tln tons, brown coal – at 4.9 tln tons [30, 31]. The organic matter of oil shales is formed from the biomass of predominantly non-vascular algae (sapropel components), to a lesser extent from land plants (humic components) and partially animal organisms. The content of organic matter, including protopetroleum, in shales is on average 45 % (in different fields from 10 % to 80 %).

The mass of organic matter contained in brown coals and oil shales can be estimated at 295 tln tons with an average specific heat of combustion of 33 MJ/kg (Qbdaf = 29–37 MJ/kg), or an average of 9.17 kW·h/kg. These reserves of oil shales and brown coals are sufficient to generate approximately 2.7×10^{18} kW·h of energy, of which 1.2×10^{18} kW·h is electricity (with the efficiency factor of a coal-fired thermal power plant equal to 45 %). Then, with an average annual per capita energy consumption power of 5 kW/person (of which 2.25 kW/person is electric energy, and 2.75 kW/person is heat), oil shale reserves will provide 100 % of energy to the Earth's population of 10 bln people for about 5,400 years, and at 2.5 kW/person (after the removal of the terrestrial technosphere into near space) for 10,800 years.

Relict Solar Bioenergy (RSBE)

It should be noted that the energy stored in brown coals and oil shales is relict solar energy received from our luminary by living organisms that lived on the planet 100–450 mln years ago. Therefore, oil shale and brown coal can be used not so much for the generation of electrical and thermal energy, but for the production of relict living humus – the basis of fertility of any soil, since such biohumus will have the same chemical composition as an ancient tree that took everything necessary for life from the ancient (relict) soil.

It is proposed not to burn fossil fuels completely, for instance, just 50–75 %. Then the combustion waste (ash, slag, sludge, dust, flue gases) must be mixed with the unburnt 25–50 % of shale or brown coal (with the addition of any raw materials of organic origin – grass, peat, sawdust, manure, household waste, etc.). The resulting multicomponent mixture, in which both organic and mineral raw materials are present, is finally processed into living fertile humus in bioreactors using specially selected communities of aerobic and anaerobic microorganisms.

The resulting relict biohumus can be added to the soil from 2–3 % – even the desert sand will become fertile with this proportion. That is, a highly fertile soil will be created around the power plants, on which, for example, gardens can be planted. Therefore, grapes, apples, and other agricultural products will become a "waste" of the operation of relict solar biofuel power plants.

This is easy to achieve, as more than 80 chemical elements that make up all terrestrial living organisms, including ancient plants, turned into coals and shales in prehistoric times, and all of them again, through the restored relict soil, will give new life to new organisms, only in 100–450 mln years.

Traditional thermal power plants emit, for instance, sulfur into the atmosphere, causing acid rains that kill all life in vast areas. But sulfur belongs to macroelements and is vital for all living organisms. For example, the daily amount of sulfur an adult requires is 4–5 g (our body contains about 100 g of it) and it is obvious that it should enter the body of a plant, animal, or human not in the form of acid rain, but in the form of organic compounds with food.

Excess heat from power plants (about 55 %) will be sent to greenhouses (in hot countries it will be converted into cold and sent to cool orangeries). Carbon dioxide will not be emitted into the atmosphere and will also be delivered to greenhouses and orangeries. There, this carbon will be utilized by plants into food carbohydrates,

proteins, fats, vitamins, and other diverse living matter – in the form of thousands of various organic compounds, including the entire periodic table, the bulk of which by weight is carbon. It should be noted that plants in greenhouses will not only absorb atmospheric CO_2 and produce food but release additional oxygen for people living nearby to breathe.

Furthermore, deep processing of some coals and shales will be carried out at relict solar biofuel power plants in order to obtain from them not only fertile humus (including liquid) but also synthetic fuel and a wide range of chemical products (aromatic hydrocarbons, oxygen and nitrogen compounds, alicyclic alcohols that have hydrogen donor properties, etc.), as well as chemical elements of almost the entire periodic table, including gold (its content in shale is up to 40 g/t), elements of the platinum group, tungsten, molybdenum, rare, rare-earth, and other metals.

For example, some Russian coals contain (in grams per ton of coal): yttrium – 254, scandium – 96, dysprosium – 384, gadolinium – 335, samarium – 211, lanthanum – 46, cerium – 89, neodymium – 806, which is more than 2 kg of rare earths per ton of fossil fuels. Therefore, Russia's entire demand for rare-earth metals (about 10,000 tons per year) can be covered by processing only 5 mln tons of such coals, and the entire world demand (about 200,000 tons per year) – 100 mln tons, which is less than 1 % of coals and shales planned for use in such power plants.

Not only coals (shales) but also the products of their combustion – flue gases, dust, ash, sludge, slag – will be used as raw materials for obtaining chemical products at biofuel power plants located in industrial clusters of linear cities. Such technologies have been in place in Russia for a long time. At the same time, the lower the energy value of the used coals and shales (i.e., the higher their ash content), the more efficient and productive they will become from the standpoint of the production of fertile humus and a wide variety of chemical elements, products, and substances at biofuel power plants. Therefore, relict solar biofuel power plants operating on brown coals and oil shales will meet the future demand for these products of the humankind on Earth for millennia to come.

Increased Soil Fertility as a By-Product of Relict Solar Bioenergy

The technology of relict solar bioenergy (RSBE) will be completely "biospheric", i.e., environmentally friendly and waste-free. Such power industry will not kill living creatures. On the contrary, it will create and foster new lives with natural, not nature-like technologies.

About 450 tln tons of living humus with a moisture content of 50–60 % can be obtained from 295 tln tons of organic matter of shales. When up to 10 % of humus (the average humus content in chernozems) is introduced into the upper fertile soil layer with a thickness of 30–40 cm (approximately 30,000 t/km^2), the said amount will be sufficient to transform 15 bln km^2 of land into chernozemic agricultural lands, which exceeds the area of the planet land by approximately 100 times, and the area of the entire surface of Earth – by 29 times.

Therefore, the terrestrial relict biospheric power industry can transform the entire land of the planet not into a desert but blooming garden, planted on the most fertile and ideal soil for life, the rich chernozem. Even if the layer of chernozem (with a humus proportion of 10 % or more) reaches a meter or higher, this will not be hard to achieve. Such bioenergy will become actually free for humankind, since the "waste" it produces – fertile humus – which will cost more than oil on the market, will pay for the production of electrical and thermal energy.

The RSBE technology, which is being successfully tested at the Unitsky's Farm Enterprise (Maryina Gorka, Republic of Belarus), can produce more than 1.5 tons of humus from a ton of brown coal. One ton of humus would enable growing about one ton of organic food. Therefore, the annual production of 15–20 bln tons of brown coal and shale, which is only 2–3 times higher than the current level of their production, will not only provide energy to 10 bln people at the rate of 5 kW/person but nourish them with healthy and wholesome (and even curative) food. Moreover, this will stop the planet desertification and will annually ramp up production of meagre and desert soils to the chernozem level on an area of more than 30 mln ha, which, for example, exceeds the area of the Republic of Belarus.

The main reserves of oil shales are concentrated in the United States – about 450 tln tons, from which more than 300 tln tons of humus can be produced (along with the generation of electricity and heat). These reserves alone are enough to provide all of humanity with energy for thousands of years to come and turn the entire planet into a blooming garden (several dozen times over) with a layer of chernozem thicker than, for example, in Ukraine. The cost of American shales as an energy resource and raw materials for the production of biohumus can be estimated at 3,000 tln USD at least (with a minimum cost of 100 USD/t), or 30,000 tln USD at 1,000 USD/t.

Food Solar Bioenergy (FSBE)

Biofuels are various types of combustible products from plant raw materials, the main advantage of which is renewability and the use of solar energy supplied to Earth. Therefore, the use of biofuels in transport, industry, and power industry will not change the existing natural energy balance of the planet.

For example, with a sugar beet yield of 100 t/ha, grown on highly fertile soil enriched with biohumus, and a sugar content of 18 %, the root crops planted on 1 ha of land can bring 10 tons of pure alcohol – an environmentally friendly fuel that is practically equal in its characteristics to natural

gas and hydrogen. But alcohol is less explosive, easy to store and use, and more readily available.

The remaining 90 tons of raw beets from each hectare will be used for animal feed and humus, which will return to the soil as organic fertilizer. At the same time, additional humus will not be required to restore the nutrients taken by beets from the soil that were used to obtain alcohol, because the plants take carbon, oxygen, and hydrogen, forming part of alcohol, not from the soil humus, but from the air (from carbon dioxide) and soil water (for example, these 100 tons of root crops contain about 70 tons of water).

To obtain 1 bln tons of alcohol annually (approximately the same amount of motor gasoline is produced in the world today), 1 mln km^2 of sown land is needed. This, for example, is 21 times less than the area of deserts on the planet, occupying 21 mln km^2 (excluding the polar deserts of Antarctica and the Arctic). Therefore, by restoring the fertility of deserts alone, humankind will be able to fill its need for environmentally friendly hydrocarbon fuel for millennia to come and provide food (through additional production of biohumus) to billions of people and animals.

The annually generated 2 bln tons (as a dry residue) of organic waste in the process of alcohol production will be used as animal feed and for the production of biohumus in biofuel power plants; that's why living matter will again return to the same soil where, for example, sugar beets were grown, not only restoring but enriching (thanks to shales) the fecundity of this farmland.

This is the real green solar bioenergy, not environmentally unsafe windmills and solar panels that produce only energy, nothing more, and require a lot of non-renewable resources both for their production and for ensuing disposal.

If 1 tln USD are invested annually in relict and food solar bioenergy (about the same as is invested today in oil production and refining) this will provide energy to all of humanity. In addition, this would enable annually to additionally vegetate an area of 330,000 km^2, equal to the area, for example, of a country like Vietnam. It should be noted that such biospheric power industry will increase the total biomass of plants on the planet (since they will grow where today's deserts are), which will not only increase the utilization of anthropogenic CO_2 by plants and the additional production of food for humans and animals but increase the production of oxygen by the biosphere, which is necessary for the breathing of 10 bln people and compensation for its withdrawal from the atmosphere by terrestrial industry, including relict bioenergy.

Infrastructure of Habitation and Settlement

Both the layout of modern cities and the logistics in them, as well as buildings and structures, do not meet the requirements for a safe, sustainable, and comfortable living of residents. Cities on the planet were built and developed spontaneously. First, hundreds and thousands of years ago, footpaths were made between individual dwellings, then they were paved with cobblestones, along which horse-drawn city transport began to move. Then asphalt was laid on the cobblestones, for the cars to drive. Skyscrapers were built around the asphalt. This is how modern megacities emerged, where life became impossible. What kind of comfort can we talk about if in some cities in order to get to work by several types of transport one has to spend 3–4 hours – half of the spare time an urban dweller has?

The modern infrastructure of habitation, especially megacities, was built not for people, but for cars, primarily for road transport, which today numbers more than a billion passenger cars alone. Traffic jams, smog, the strongest noise from the city traffic, dirty air, soil saturated with hundreds of carcinogens (exhaust gases, anti-icing agents, tire and asphalt wear products). Streets, backyards, along with surface, overland, and underground garages and car parks are packed with millions of cars.

Cities on the planet have occupied vast territories, and on the best lands – these lands have been withdrawn from biospheric life cycles, as they are occupied by buildings, structures, city roads, and infrastructure. For example, the world largest Chinese city of Chongqing (82,400 km^2) is practically equal in area to a country like Austria (83,800 km^2).

A significant part of land on the planet (even the best plots) is today "paved over" and "buried" under railway sleepers – it is the land with a size five times that of Great Britain [22]. The fertile soil adjacent to the roads is degraded on a territory that is larger by an order of magnitude. Due to imperfect transport, about 1.5 mln people die on the roads every year (with account of post-accident deaths in hospitals) along with hundreds of millions, if not billions, of large and small animals; more than 10 mln people get into accidents, are injured, become disabled and crippled.

By the end of the 21st century, more than 100 mln people may die on the world roads, while about a billion will become disabled and crippled. Electric cars – a fashionable trend in transportation – will not save these lives in the future, they will kill and maim people on the roads in the same way. But these lives can be saved, and the lands returned to land users, if we change the structure of the settlement and habitation of the urban population, make cities pedestrian, and move transport to the second level – to a height of about 10 m.

Linear City

Linear cities, harmoniously blended with the environment of any natural and climatic zone on the planet [32, 33], will become an alternative to modern megacities. Not only do they not take away fertile land for building construction but create more of it. The cities that are provided with everything of own production that they need: clean energy, organic food, artesian (spring) drinking water. The cities, which will help deserts to disappear from the planet, which, in the 21st century, will be transformed into a blooming garden in which all future humanity will live and work safely and comfortably.

It is more reasonable to place linear cities at a height of at least 10 m above the current ocean level. If its level rises in the distant future, in hundreds of years (be it through a natural cyclical global warming or a warming caused by human activity), the ocean will not flood these settlements.

The linear city is made as pedestrian clusters connected to each other by an urban "second level" electric communicator moving at a speed of up to 150 km/h – the Unitsky String Transport – as the safest, most energy-efficient, and environmentally friendly type of passenger and freight transportation [1].

Through the linear city or parallel to it passes the transport and communication corridor uNet about 100 m wide – the high-speed uST air routes (speed up to 500–600 km/h), hypervelocity uMach routes (speed up to 1,200–1,500 km/h), located in forevacuum tunnels, and cargo systems [22]. To ensure comfortable movement, in which centrifugal accelerations should be below 1 m/s^2, the radii of curves on routes (both vertical and horizontal) at a speed of 500–600 km/h should be at least 20–25 km, and for 1,200–1,500 km/h – at least 120–150 km. Hence, the linear city itself can be winding, but high-speed routes along it must be as straight as possible.

With an average population density along a linear city of, for instance, 2,000 people/km, in order to accommodate 10 bln people, the total length of cities built along the uNet communication network and combined with relict solar biofuel power plants, power transmission and communication lines, will be 5 mln km. Then the network of linear cities will occupy an area on the planet of about 5 mln km^2, or 1/27 of Earth's land (excluding the coldest continent – Antarctica), while 26/27 of land can be allocated for national parks, reserves, wildlife sanctuaries, and reservations with sparing land tenure systems.

By the way, the area of deserts on the planet (excluding the polar deserts of Antarctica and the Arctic) is four times greater [34]. That is, if the deserts are greened up and linear cities are built only there, 40 bln people will be able to live in them, supplied with everything they need: housing, food, drinking water, energy, transport, work, rest, and recreation. After all, it will be much easier and cheaper to do for all of us than, having finally exhausted, mucked up, and spoiled our home planet, fly to a distant, cold, and alien Mars in order to lead a wretched existence there in spacesuits, without local organic food, fresh drinking water, and crisp air.

At the same time, such linear cities will occupy land nominally, since gardens will grow on the roofs of all buildings and structures (in greenhouses and orangeries). Natural biogeocenoses and biosphere ecosystems will be created there, even where there are deserts and permafrost today.

The total length of the uNet network, counting the transverse lines and "second level" roads, entering protected natural areas and natural resource deposits, will then amount to approximately 10 mln km (for comparison: the total length of the world network of all types of roads is now 68.9 mln km [35]).

Near the residential clusters, along or across the linear city, there will be infrastructural clusters with other functions: scientific, educational, industrial, sports, shopping and entertainment, recreational, etc. To improve the logistics, and maintenance of production facilities, including the relict solar biofuel power plants with a large volume of freight traffic of raw materials and humus, infrastructure clusters may be located outside the residential area – in the area of the uNet transport and communication corridor. The required volume of transportation through the cargo component of the global network is about 10 bln tons per year of shale and brown coal and about the same amount of fertile humus.

The average speed of public urban transport – uPods (rail electric vehicles on steel wheels) – in the linear city will be 60–80 km/h and more. Having no obstacles to traffic (intersections and pedestrian crossings, cars, trams, and buses, snow or sand drifts, puddles on the roadway, etc.), it will be the safest and by an order of magnitude faster urban public transport in the world. For example, the fastest transport today is in Berlin, where its average speed is 6.5 km/h (for comparison: in Washington it is only 2.8 km/h) [36].

The uST with a string-rail track structure of a sagging type is the most energy-efficient type of urban road out of all theoretically possible ones, since it automatically recovers energy when moving from station to station. When leaving the station, the uPod, moving downhill, accelerates to the rated speed (for example, 100 km/h in the middle of the span) only due to gravity, i.e., without using the engine. In the second half of the way, the uPod, moving upward, is decelerated by gravity, i.e., without using the brakes.

In such a system of operation, similar to the pendulum swings, the potential energy of a uPod is automatically converted into kinetic energy and vice versa under the laws of physics, and not with the help of mechanical recuperators, which, as a rule, have a low efficiency factor. Energy is needed here only to overcome the aerodynamic drag and rolling resistance of a steel wheel, which is about 5–7 times less than is required when traditional urban transport (bus, tram, train) moves along a horizontal track. Therefore, to perform similar transportation work, the network of uST urban routes located at the second level will require 5–7 times less energy than an ordinary urban transport network at the first level of the same length and capacity.

The uST track structure is designed in such a way that electrical and information networks will be embedded into it, providing electricity and communication for both the clusters and the linear city as a whole with the entire infrastructure: social and cultural, shopping and entertainment, scientific and industrial, and others.

Each cluster will have one or several relict solar biofuel power plants with a total capacity of 10–20 MW (depending on the number of cluster residents), located outside the residential area, which will produce up to 50,000 tons of fertile humus over a year. This would enable, for example, annually transforming up to 1 km^2 of desert (this is equal to the area of an average residential cluster) into fertile land such as chernozem. Therefore, in 50 years of operation, the world-wide linear city will be able to provide an increase in soil fertility to the level of rich chernozem on the entire Earth's land, including mountains and deserts.

Linear City Cluster

The cluster with an area of 1–2 km^2 (with dimensions in plan of about 1–1.5 km) is planned to be constructed as a pedestrian urban-type settlement. It will comfortably accommodate from 2,000–3,000 people (based on 500 m^2 of land per person, or 25 ares for an average family of five people) up to 7,000–10,000 people (200 m^2/person, or 10 ares per family). The cluster is designed to be built on land, but with minor changes it can be built on the sea shelf, or (if buildings and structures are made buoyant) in the open sea.

Dimensions of the clusters are based on the need to connect their centers with each other with an urban uST of the sagging type – one span, without intermediate supports. It is known that having frequent stops of the urban transport (in less than 1 km) significantly reduces the average speed of rolling stock, which would lead to an increase in travel time along a linear city. And on spans longer than 1.5 km, the string-rail track structure will sag excessively (under its own weight and the weight of the rolling stock), which will require passenger stations be located at heights of 50 m or more. Therefore, the dimensions of the cluster in plan view and the length of spans of 1–1.5 km are the best possible both from the viewpoint of pedestrian and urban transport logistics, and in terms of technical and economic indicators.

The residential area will be divided into blocks, separated by a green strip 100–200 m wide, with common areas to be arranged for the cluster residents and guests: leisure and sports areas, various public buildings and structures, sports grounds, a stadium, a health center, a medical station, shops, cafes, workshops, a kindergarten, a school, etc.

In the center of the cluster, there will be a high dominant building with a uST station on one of the floors (or on the roof) within walking distance (reaching it from any point of the cluster takes no more than 10 min). In the center of the green strip at a height of more than 10 m, there will be a string-rail track structure (visually light and delicate, even casting no shadow), which, with the same capacity, will be at least 10 times cheaper than a traditional underground metro.

Silently moving along air rails will be the rolling stock of the high-speed sky metro – rail-tracked electric vehicles on steel wheels, called uPods, which are at least three times more power-efficient, i.e., greener, than a traditional electric car. The height of the safe movement of rolling stock at the lowest point of the track (in the middle of the sagging span, namely in the interval between adjacent clusters), will be no less than 6 m to the bottom of the moving suspended uPod.

Residential buildings will be united into a single architectural and functional system – into a multi-apartment "horizontal skyscraper" (i.e., a high-rise building "lying on its side"). The dimensions of the "skyscraper", including its length, can vary over a fairly wide range – from 100 m to 1 km. Each house with a living area of 100–300 m^2 is designed to accommodate an average family of five people. The houses will have three floors – semi-basement, living floor, and attic.

It would be expedient to have them built as frame houses with panels made of vacuum glass (the author's know-how) – the thermal insulation properties of such panels with a thickness of 20 mm are equivalent to a brick wall 1.5 m thick. If necessary, such panels can be transformed into screens where any images can be displayed. The main material for construction is sand, and there is enough of it on the planet for trillions of such "skyscrapers".

In terms of energy efficiency, each "horizontal skyscraper" of the cluster will be designed as a "house plus energy" (as per the European classification), when a house with all the utility equipment fitted (solar panels, collectors, heat pumps, recuperators, etc.) generates more energy than it consumes.

Conventional roads in the cluster will be green (made of aerated concrete with grass) and combined with pedestrian and bicycle paths and suitable for light electric vehicles. Provision is also made for heavier traditional vehicles, such as an ambulance, a fire engine, and farming equipment. Dirt roads (with grass) will be made between the houses for the access to each household plot.

Therefore, each cluster is a self-sufficient urban-type settlement, although as per the living arrangements it is more likely to belong to rural settlements. It will be provided with everything of own production that it needs – food, water, energy, transport, and all the services needed in a contemporary village. This will ensure food, energy, environmental, infrastructural, social, and other security of the linear city even amidst pandemics, lockdowns, or other natural and man-made disasters.

Optimization of urban planning and development, of buildings, structures, and infrastructure ("linear skyscrapers", roads on the first and second levels, adjoining outdoor space and common land plots, utility systems, landscaping, etc.) will reduce the cost of housing and living in a linear city by 2–3 times in comparison with the conventional urban development, while improving the quality of the living environment and the standard of living of urban residents.

Food Capacity of the Biosphere

Food Production for Humanity

The total dry biomass of the biosphere is estimated at 2.4 tln tons, of which over a trillion tons is carbon [17]. At the same time, the main biomass on the planet is green land plants, while all other living organisms (animals and microorganisms on land and in the ocean, as well as aquatic plants) have a total mass of only 38–46 bln tons (less than 2 %), counting the underground biomass located at depths of up to 5 km.

Contemporary humankind is about 350 mln tons of biomass in live weight (about 45 kg per person, including children), or about 100 mln tons in terms of dry biomass (about 13 kg/person), which is about 0.004 % in comparison with the entire biomass of Earth.

The large biomass and variety of terrestrial living organisms are accounted for by the presence of humus, a complex organic matter, due to which any soil becomes fertile. In the most fertile soils – chernozems – humus comprises up to 10–15 %.

The basis for the production of organic food for humans is living fertile soil.

An average person (considering all age groups) consumes about 700 kg of food per year, or about 150 kg in terms of dry matter. As a result of metabolism, each person excretes approximately the same amount of waste into the environment, primarily through his digestive system. If this waste, converted into humus, is brought back into the same soil on which the crops were grown, then the natural circulation of living matter, disturbed by contemporary humankind, will be restored.

Currently, food grows in one place, and waste is generated in another, thousands of kilometers away. At the same time, the annual removal of nutrients from living fertile soil on the planet (billions of tons) is not replenished, as mainly only three chemical elements (nitrogen, potassium, phosphorus) are brought back into the soil, although plants, during their growth, take almost the entire periodic table from it. Moreover, simple and soluble chemical fertilizers produced by industry are brought into the soil of farmland, instead of complex organic insoluble humates created by life, as it was during previous hundreds of millions of years of the evolution of life and Earth's biosphere.

Agricultural Production in a Linear City

It is impossible to imagine a real EcoHouse without the production of a variety of organic foods for the needs of each household – vegetables, fruits, meat, milk, eggs, mushrooms, fish, etc.

The roofs of houses (attics) of a "horizontal skyscraper" in each cluster of a linear city will be made as glass greenhouses (in hot countries – orangeries), which are combined with each other and have a road along the entire length of the "horizontal skyscraper" in the center for service vehicles. The semi-basement floor built on the common foundation for the entire length of the "skyscraper" will also have a road in the center for service vehicles. This would enable not only having vegetables and fruits in greenhouses (orangeries) on the roof but breeding poultry, fish, and seafood, both marine and freshwater, in the semi-basement, as well as growing mushrooms and other products for consumption. At the same time, an enclosed agricultural zone can be attended to by a gardener and an agronomist common for each "skyscraper" and hired by each household.

Microgreens and green food, nourishing the residents of the linear city cluster (for people and animals), will be produced in greenhouses and orangeries, including those made as vertical farms. According to this technology, a solution with nutrients is supplied to the root system of plants, and green shoots sprout up from plant seeds within 5–7 days. This technology is natural, in contrast to the conventional nature-like hydroponics based on chemical mineral substances, as evolutionarily plants are formed to feed on organic humus.

Humus – insoluble salts of humic acids stored in the soil – is converted into a soluble form by a community of thousands of species of aerobic and anaerobic soil microorganisms directly in the root system of plants. Therefore, agricultural farms of a linear city will employ humusoponics – according to this technology plants feed on liquid humus, in which insoluble salts of humic acids have already been converted into a dissolved form. Such experiments have been successfully conducted at the Unitsky's Farm Enterprise in Maryina Gorka.

Microgreens on humusoponics are natural organic foods, originally rich in easily digestible nutrients and vitamins. Their cultivation technology has no chemical fertilizers, protection chemicals (pesticides, herbicides, and other toxic chemicals), and GMOs. For example, in comparison with dry food for animals (mixed fodder, meadow hay), humusoponic fodder from wheat germs is better absorbed, is more energy-intensive, and contains 2–3 times more proteins and fats, while it exceeds dry food ten-fold in terms of its content of carbohydrates, sugar, and vitamins. It is also much healthier and more efficient than fresh grass and silage. Unlike other forage eaten outside the pasture, this feed comes in the living form at the peak of its growth, preserving all the vitamins and digestive enzymes that animals need so much, especially in winter.

Another fundamental difference: the animal eats not only the aboveground part but the remnants of seeds with starch, and the root, rich in sugars and proteins. At the same time, diverse organic waste materials generated in the cluster can be used as a substrate: straw, press cake, and even specially prepared wood chips, which microorganisms and plant roots convert (ferment) into easily digestible food. The result is a balanced, complete, and stable in its composition and quality fodder, which ensures the herbivorous animals get all the variety of essential nutrients they need.

Regardless of the season and natural and climatic conditions (droughts, torrential rains, heat, and frost), humusoponic installations will be able to provide not only animals but people with fresh green food all year round, which is especially important in case of vitamin deficiency in winter.

Growing 1 ton of green forage requires about 2 tons of water, while the conventional field method requires 400 tons, i.e., 200 times more. In the conventional preparation of animal fodder, about 1 ha of land per head is needed, while the proposed technology of all-year-round vertical humusoponic farms, arranged, for example, in the semi-basements of buildings and structures, requires about 1 m^2 of floor, which is 10,000 times less. This also excludes tillage practice and fertilization, as well as operations like sowing, harvesting, transportation, drying, etc. (all of this on the natural areas 10,000 times greater).

Year-round production of agricultural products in greenhouses under the protected ground conditions, for example, in the Netherlands today, yields on average up to 50 kg/m^2 per year. Then, to sustain a family of five with fruits, vegetables, berries, and herbs, up to 100 m^2 of greenhouse area would be enough. If greenhouses are placed on the roofs of "horizontal skyscrapers", i.e., replace conventional roofs with year-round greenhouses (in hot countries – orangeries), then each house would be able to feed the family living there with plant food. At the same time, such a house does not destroy natural soil, as it will be moved to the roof from under the foundation of the house (even if it's desert sand), enriched with humus and become greener, i.e., more productive.

Mushrooms, fish, seafood, small animals (such as rabbits), and poultry (such as quails) will also be grown and bred in the semi-basement of the "horizontal skyscraper" (i.e., in each house).

In order to populate the linear cities described above with 10 bln people, 2 bln dwelling EcoHouses will be required, if we assume that a nominal average family consists of five people. With the maximum estimated area of greenhouses (40 m^2 per person), these EcoHouses will occupy an area of no more than 400,000 km^2, or only 1/337 of Earth's land (excluding Antarctica), or 1/1,275 of the planet surface (houses can be made buoyant and placed on water, for example, on the sea shelf). At the same time, such EcoHouses occupy the land nominally, since the area of living fertile soil on the planet will not decrease, but increase – it will appear on the roofs in settlements even in the place of today's deserts and permafrost.

Production of Meat and Biohumus

Let's consider the production of organic meat using the example of cattle, since cows allegedly cause much more damage to the Earth's ecology than, for example, cars and airplanes combined. This conclusion was made by experts from the Food and Agricultural Organization (FAO) of the United Nations [37]. According to the FAO, about 1,5 bln cows live on Earth, emitting 18 % of supposedly all 100 % of greenhouse gases, which indeed exceeds the emissions of all transport on the planet.

In fact, as described above, these 18 % are taken from the 22 % of the greenhouse gases – from carbon dioxide. That is, their effect is only 0.18 × 22 % = 4 %, since the main greenhouse gases – water vapor – for some reason were not taken into account, although the significance of H_2O in creating the greenhouse effect in the Earth's atmosphere, as described above, is 3.5 times higher than CO_2.

A cow eats about 20 tons of green fodder per year and produces roughly 20 tons of manure. Hence, all 1.5 bln cows in the world will require about 30 bln tons of fodder; they will provide 30 bln tons of manure, or in terms of dry matter – 7.5 bln tons, or 1/26 of the biomass produced by the biosphere.

This annually dying biomass, this grass, regardless of whether cows ate it or not, would still be processed by the biosphere during one season into humus – by the same microorganisms as in the stomachs of cows, with the release of the same (and in the same amounts) fossil gases, primarily methane and CO_2.

So, cows in no way change the biosphere processes and do not harm Live Nature, because the biosphere is completely indifferent to where this organic matter with the absorption of oxygen and the release of methane and CO_2 was processed – in the soil or in the digestive system of an animal. At the same time, cows speed up processing organic matter into humus, since this living biofactory turns dry grass into almost ready-made biohumus within a day, while in the soil these processes take several months.

Each cow produces several items, among which the surplus value of its biospheric waste – manure and urine as organic raw materials for the production of humus – is commensurate with the cost of milk and meat it produces.

One cow can annually supply 100 kg of nitrogen, 50 kg of potassium, and 140 kg of phosphorus as a natural organic fertilizer with almost 100 % assimilation in soil [38]. In addition to replacing nutrients taken out by plants from the soil, all types of manure increase the proportion of humus in the soil and restore the fertile layer of any land.

Therefore, the vilification of organic beef in the works of some researchers, including under the auspices of the UN, is just a commissioned work to transfer human nutrition to synthetic meat in the interests of the producers of this dangerous food product.

The aforementioned 30 bln tons of manure, converted annually into living fertile humus, for example, in relict solar biofuel power plants, will cost about 10 tln USD on the world market. These 30 bln tons of biohumus will make it possible to produce so much organic agricultural products (primarily in linear cities) as to feed more than 20 bln people.

A car, on the other hand, does not produce anything useful, except for transport services, while its industrial waste (exhaust gases, wear products of tires and asphalt, deicing salts, etc.) contains more than 100 carcinogens that can poison all life on the planet in territories exceeding, for example, an area of Great Britain several tenfold. Therefore, comparing a cow and a car from the standpoint of danger to the biospheric habitat is not only incorrect but blasphemous.

Recycling of Civilization Waste (Trophic Capacity and Technogenic Bioecology)

A person, on average, excretes 1.5 kg of urine and feces per day, containing a large amount of nutrients, including almost the entire periodic table. This liquid should not be discharged from the toilet directly into the ground, where it will overload the soil and can enter groundwater or nearby bodies of water.

Food waste generated in the kitchen – from banana and potato peels to fish bones and scales – is up to half of the food consumed by weight. All of this organic waste can be separated from water, for example, in a dry sewerage, which will yield approximately 150 kg of dry organic matter for each person annually – about the same amount by weight as they eat.

Therefore, people can feed themselves with their waste if in the place where they live, all organic waste, including sewage runoffs, is processed into humus, which enriches the farmland soil and new food grows on it. This can be done in an environmentally friendly way if you use toilet facilities and sewerage, where organic matter is separated from water.

The water of a linear city getting into the sewerage (on average about 50 tons of hot and cold water per person per year) can be used later as service water and for watering household plots (for example, growing a ton of apples in the open takes about 700 tons of water). At the same time, only dissolved minerals and organic fertilizers will remain in such water, mainly from urine and feces, totaling less than 0.01 %. These organic substances in such amounts are completely safe for the soil, moreover, they will increase soil fertility and the yield of organic products on household plots. Just as it was in the pre-industrial era, when all organic waste on the farm, including that from domestic animals, was disposed of directly on the household plot.

Separation of water from dissolved organic matter in sewage drains is much easier to be done than, for example, desalination of seawater containing hundreds of times more mineral salts (about 3 %), whose molecules are much smaller than the molecules of organic substances. Therefore, modern technologies of water desalination can be employed also in the treatment of sewage in order to regulate the content of substances dissolved in them and cut off pathogenic microflora and microfauna, which are even larger.

For 10 bln people, this will amount to 1.5 bln tons of dry organic matter waste annually (less than 1 % of the living matter produced by the biosphere in dry weight) and 500 bln tons of sewage water per year, which will be used multiple times, primarily for the output of agricultural products in linear cities. With an average global rainfall of about 1,000 mm in a year and an average land area in a linear city, for example, of 300 m^2 per person, recyclable sewage water (50 tons per person in a year) will make up 1/6 of precipitation and will become an effective biologically active additive thereto, increasing soil fertility on household plots.

Biologically Safe Capacity of the Biosphere for the Technogenic Human Population

About a trillion species of living organisms currently populate the planet, of which less than 0.0001 % have been studied: animals, plants, fungi, and microorganisms (microbes, viruses, bacteria, protozoa, etc.), while non-microscopic species (visible with the naked eye) account for no more than 1 mln species [12]. All these types of living beings have been residing in our common home – the biosphere of planet Earth – for millions, and some for billions of years. In the course of evolution, everything here has been perfectly matched toward one another, so everything in the Earth's biosphere is harmoniously arranged, there is nothing redundant, and there is no need to "improve" anything at all.

We do not need to fight microorganisms, we need to learn how to coexist with them. We will lose any war declared on microbes. Because more than 10,000 species of bacteria, viruses, archaea, and fungi live in our body – the human microbiome has about 100 tln bacterial cells. They constitute a highly complex human ecosystem and are the basis of the immune system, especially the intestinal microbiota, which consists mainly of soil microorganisms. A person has much less of one's own cells – about 30 tln, so you can harm your own cells, as it is impossible to fight one and only representative of unwanted viruses,

(for example, COVID-19), without disrupting the symbiosis of the human body with trillions of beneficial microorganisms of thousands of species living in it, which has developed over millions of years.

The medicine prescribed by the doctor fixes one thing and breaks another. It is not the treatment itself that is more important, but the prevention of diseases by strengthening the immune system, which is our universal medicine. This requires: a healthy lifestyle, both physical and spiritual; proper and healthy nutrition, grown on living fertile soil without chemical fertilizers and pesticides; living natural spring low-mineralized drinking water; clean air replete with phytoncides from medicinal plants and flowers.

Even if 100 bln people live and work on the planet, their biomass will be only 0.05 % of the biomass of the entire Earth's biosphere. And this in no way will lead to global problems, if, of course, humanity stops fighting nature, begins to coexist with it, as one of the biological species, according to the biospheric laws that have developed over billions of years of evolution.

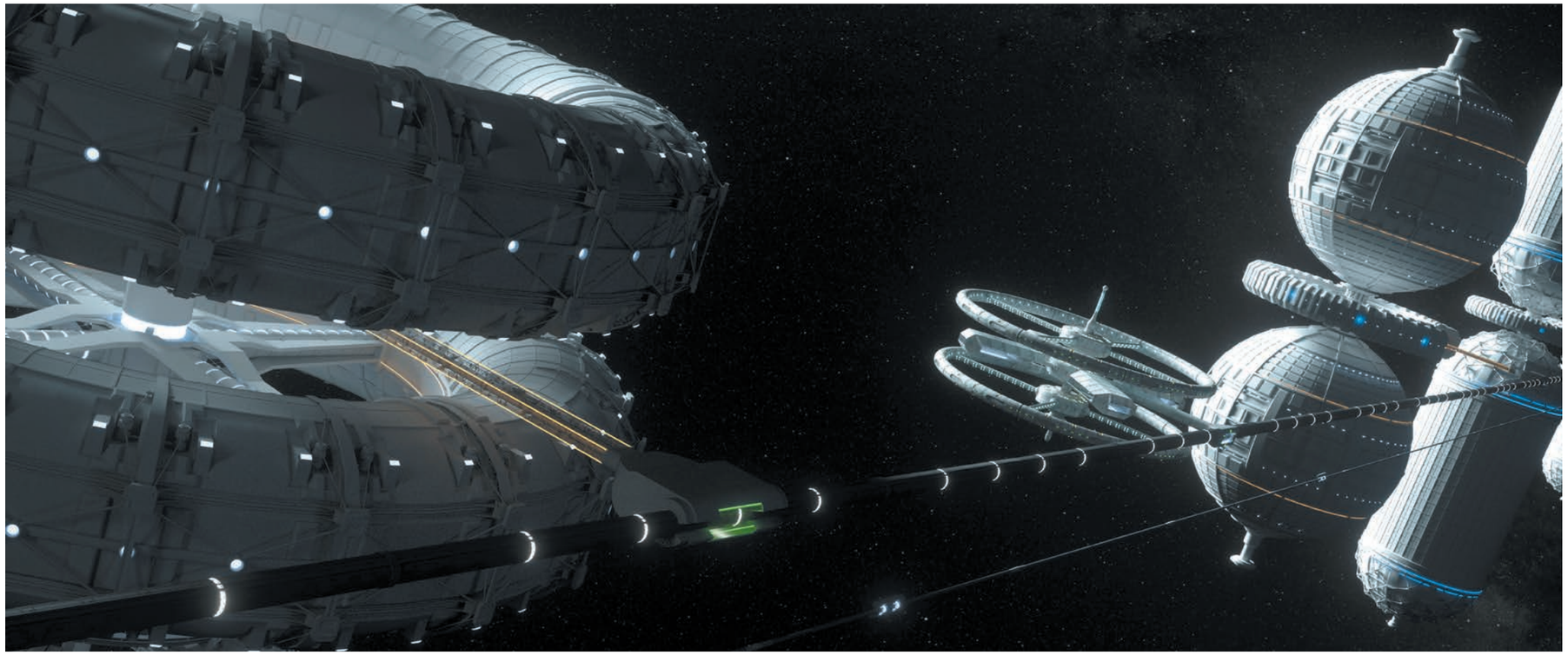
Problems are created not by humanity itself, as a living substance, but by the dead technosphere created by it, which, like a cancer cell of a sick person, destroys its owner, in this case, the biosphere, which occupies the same niche in space. But today's humanity is ill on the system level, and if it is not treated on the system level, it will die in the foreseeable future.

The civilization that we know and of which we are a part, can not only be saved but provided with a driver for sustainable development for millennia to come, if we bring the industrial part of the Earth's technosphere into near space, creating a paradise and planting gardens on Earth (also in lieu of current deserts), which could feed tens of billions of people. At the same time, the remaining part of the technosphere on the planet must be made friendly to the biosphere.

To do this, we need to restructure (reload) the following:

- **agriculture.** It must be localized where people live, within walking distances, making it highly productive on living fertile humus, completely natural and organic, without the use of chemical fertilizers, pesticides, and genetic modification. Food will be produced here, while its waste, including sewage runoff, will be turned here into biohumus, on which new food will grow, which corresponds to the natural cycle of living matter in the biosphere;
- **terrestrial transport (land, water, air, space).** All transport must be moved to the second level, without linear support on the surface of the earth, and make it by an order of magnitude more efficient, safe, and environmentally friendly. After all, not only modern roads are taking away land but modern airplanes, sea ships, and space rockets must have huge airports, seaports, and spaceports (thousands of hectares each). There are thousands of them on Earth, and they occupied the best lands in every country. All this land can be returned to land users, and gardens can be planted there. And there is only one type of transport that meets these requirements – this is the Unitsky String Transport. That is why it will become the leading mode of transport on the planet as early as in the middle of the 21st century;
- **terrestrial power industry.** It must be made biospheric, by analogy with living organisms, which, while generating energy, produce living fertile humus as the final biowaste. This technology can be employed only by relict solar biofuel power plants (using brown coals, shales, peat, wood, and any other organic energy raw materials), which over the span of 50 years can transform the entire planet dryland in a blooming garden, planted on the rich chernozem, even on the place of today's deserts;
- **residential and industrial infrastructure.** It should be located in linear cities with a total length of about 5 mln km, the total area of which for 10 bln inhabitants will be about 5 mln km^2. Such cities will occupy only 1/27 of the land area, and the remaining 26/27 of the land area will be rendered to national parks, reserves, wildlife sanctuaries, and reservations with moderate land tenure systems. The main infrastructure facility on the planet will be the Equatorial Linear City (ELC) with a length of about 40,000 km, which will pass along the equator of Earth [39]. The ELC will become a land-based research, production, and operation platform for bringing the environmentally hazardous part of the terrestrial industry into space and its functioning;
- **space industrialization.** It will have to be carried out on a large-scale non-rocket basis by the middle of the 21st century, in order to gain access to the infinite resources of the Universe – energy, mineral, spatial, and fundamentally new technological capabilities, such as zero gravity, deep vacuum, technological purity (without dust and microorganisms), and others [40]. Only the General Planetary Vehicle (GPV) propelled solely by electric power is capable of solving this problem. After all, the GPV can deliver in the environmentally safe and affordable fashion (about a thousand times cheaper than a rocket) up to 10 mln tons of cargo and up to 10 mln passengers into orbit in one flight, with a system efficiency factor of 97–98 % [13, 40].

The Industrial Space Necklace "Orbit" (ISN "Orbit") created around the planet in the equatorial plane will become a springboard for expansion of the Earth's civilization into deep space and fulfill the tasks of protecting the planet from space threats, including asteroid ones. While outer space is explored, a significant part of the Earth's civilization will begin to live in orbit in EcoCosmoHouses (ECH) [41], where enclosed ecosystems will be created, duplicating the best natural and climatic conditions of the planet (subtropics), including gravity (by means of centrifugal forces). But still, the major part of humanity, united by common goals and objectives, will live in its cradle – on planet Earth, which has been turned into a blooming garden.



New Socio-Evolutionary Level of Human Development

A fundamentally new infrastructure of settlement, living, working, and recreation of people in linear cities, dovetailed with terrestrial nature, without violating its local and global biogeocenoses that have developed over millions of years of evolution, enables us to look differently at societies historically formed on the planet that are part of the structure of our modern technogenic human civilization.

Having invented the first machine as his servant, man gradually, from generation to generation, socially mutated and turned into its servant, and then into its slave.

We cannot imagine life today without a smartphone and a car and we care about them more than about our health. For example, the creation and implementation of the iPhone and MacBook technologies were more important to Steve Jobs than the functioning of the pancreas in his body, from the cancer in which he died at the age of 56.

After all, we do not put our smartphone in the microwave for a night, because we realize it will quickly fail to function, although we can put it next to our pillow, closer to our brain. And we can even build a house under a high-voltage power line and easily cross it dozens of times a day.

We are afraid of high voltage in the socket, but do not attach importance to getting electric shocks from a doorknob, because we are dressed and booted in an electrified insulator, although our ancestors walked barefoot and had the electrical potential of Earth. We are not bothered by the fact that sparks fly when we comb our hair, which speaks of a high, about 100,000 V, electrical voltage around our head. Although we know that our nervous system and brain are super-complex low-voltage systems that exchange weak electrical impulses that are very sensitive to external electric and electromagnetic fields.

We are afraid to walk up to a verge of the roof of a 20-storey building, but not afraid of the collision with an oncoming car at a speed of 70 km/h, although hitting the ground after falling from a height of 80 m will happen at the same relative speed.

Man keeps on moving further away from the Live Nature that gave birth to him and into the inanimate world of machines, devices, and artificial intelligence. We are happy when our 5-year-old child is confidently working with a computer, but are not upset when he/she is convinced that bread grows on trees, like apples, and sausage is grown in seedbeds, like radishes.

The technocratic development vector of our civilization, driven by four sectoral industrial technologies – agriculture (food sector), transport and communications (communications sector), power industry (industrial opportunities), infrastructure of living, production, and work (habitat) – is going down a blind alley due to the imperfection of these outdated – one might say, ancient – technologies that do not meet the civilizational requirements even of today, let alone the future. This shows that under the guise of global warming, deindustrialization, decarbonization, and other vilified global problems of our time, there is an attempt to zero out the civilizational settings and break the existing industrial civilization code.

It is well known that the solution to any complex problem must always be sought at a higher level of understanding.

The main causes of the global problems of our time are the activities of humankind on the platform of the mind. In order for these problems to become a thing of the past, every human person and humanity as a whole need to rise to a new macrolevel – the level of reason.

Only reason distinguishes us from animals on a system level. Animals have intelligence too, but don't have reason. The mind is responsible for food, procreation, and other bodily needs required for survival. Therefore, even the very same coronavirus is smart enough not to set a goal, for example, of annihilating its habitat – the human body, where it settles.

Reason is responsible for spirituality – self-knowledge, self-development, human feelings and emotions, morality, ethics, art, culture, improving relations with other people and the surrounding nature, and other spiritual values.

Only the presence of reason makes each person a social person. Concepts such as "society", "sociality", "socialization" have a very similar meaning. All these concepts can be replaced by two simple and familiar to everyone words: human relations.

The presence of reason enables us to consciously improve and develop our relationships with other people, the surrounding nature, and with the entire Universe as a whole. Reason manifests itself in every person as spirituality and conscience. According to all teachings – spiritual, philosophical, religious – each person should improve and develop himself, building elevated relationships at all levels. For this, Nature gave him reason.

While possessing both mind and reason, man has become binary: he is both a social person and, simultaneously, an individual person.

Individual means intelligent. Social means reasonable. The more reasonable a person is, the higher his spirituality is and the better he builds relationships with other people, with the surrounding world, and nature in all its manifestations.

With the development of industrial technologies in a consumer society, aimed at satisfying bodily and mental needs and pleasures, less and less attention is paid to improving the inner world of people, the level and quality of their relations both with one another and with the outside world. And the less humaneness remains in people, the more inhumane offences they commit, the more chaos they bring to our world, destroying the God-given Live Nature in our common home – planet Earth.

The technology-based human civilization created by people is a civilization of very intelligent, but very unreasonable people. Modern human began to value individual comfort much more than interpersonal relationships. Such people are still classified by contemporary medicine as "mentally unsound".

The wider a gap a person has between mind and reason, the worse it turns out for the individual and for the spiritual environment of his habitation – the society. And, vice versa, the more conscious the relationships between people in society are, the faster they and society succeed in all areas of their activities with significantly less effort and resources. This is where the rationality of each person should be manifested – in the realization that his main personal benefit is his spiritual development, in the development of social and interpersonal relations not only with other people but with the surrounding world.

The real progress of our technogenic civilization, built on engineering and scientific technologies and discoveries, should consist not so much in the development and improvement of industrial achievements, as in the progress of humaneness in people making up our tellurian and precisely human civilization, and not any other (like the one of dolphins, ants, or bees). The time has come to build a civilization consisting not so much of intelligent techno-consumers as of socially reasonable people, for which they need to learn how to create and make social inventions and discoveries, along with technical ones.

Humaneness is a cultural, moral, and community-social state of an individual, the development of their mind, and acquisition of full-fledged morality and ethics of interpersonal relations, conscious responsibility and a holistic understanding of real life on Earth, in the biosphere of which there are

billions of species of living beings – billion-year long-livers and real owners of our common planet, which is a small grain of sand (rather a microscopic speck of dust) in the Universe, infinite in time and space.

Humaneness and spirituality reveal the fullness of the individual nature of each person, his unique abilities and talents. By developing these qualities in oneself, one begins to feel the fullness and wealth of the Earth's life – one's own and that of society created together with the likes of oneself.

The completeness of morality is when it's not only our life that we want to make happy, versatile, and high-quality but the lives of our relatives and friends, based on the logic of the "Six handshakes rule" – out of love for them, relying not on self-profit, but on higher-order values.

Conscious responsibility is when we take personal responsibility not only for our life and health (physical, spiritual, and moral) but for the health and life of our loved ones, humanity and the planet as a whole, and do not shift this responsibility onto others.

Integrity of understanding is when we consciously develop our reason towards understanding how the real (and not virtual and digital) world around us works and functions, and what is the meaning of each life and its purpose.

The deeper and wider a person reveals his individuality and hidden talents, the richer, better, and more interesting his/her relationships with other people will become. The divine principle of unity in diversity put in by nature is possible only with the disclosure of people's personal individual essence, which will only enhance and increase their enjoyment of life and relationships with one another.

The more femininity there is in women and the more masculine qualities there are in men, the more attractive they will become for each other, the stronger and more stable their family unions will be. Here lies the divine wisdom so that life should not degenerate, but develop eternally from the simple to more complex, more sublime, and higher quality. It was sociality and interpersonal relations that enabled several thousand primitive people to create their first engineering technologies and, over several thousand years of evolution of engineering creativity, to develop into a modern technogenic mega-society – humanity, numbering many billions.

Reason, like life itself, has an anti-entropic nature. This means that reason always strives to increase and arrange knowledge, to understand the essence of the Universe and in its highest manifestation – to comprehend the divinity of Live Nature and to restore material and mental relations and connections with it, lost by the techno-consumer human during the development of industrial technologies.

Man, as entropic matter, is doomed to decay. His intellect, i.e., reason, is an anti-entropic tool, the purpose of which is to elevate the non-material component of his personality – spirituality. Man develops his individual and, accordingly, collective reason only when, relying on his talents and experience, he brings benefits not so much to himself as to those around him. This is the essence of the concept of human humaneness.

According to all existing religions, the goal of any human life is for each person to be able to reveal all the best in himself and to be reunited with the Universe that created him. The main goal of the leadership of each nation state should be precisely helping people living there to do this. This is their social and spiritual responsibility to society.

People who are on the platform of the mind, become individualists and morally degraded due to the false priorities and goals of the consumer society that are strongly imposed upon from every media in the highly secretive interests of the global businesses that created them.

In the current reference frame, it is economic growth and GDP that are determinant for all states, not the development of a citizen of the country as a spiritual person. The true priorities should be totally different. There is a well-known saying: don't put the cart before the horse. Material well-being is the cart. While the development of human qualities in a person is the horse of civilizational progress. Correct and safe onward movement is when the horse is harnessed to the cart, not vice versa.

If people move from the economic reference frame – from the consumer society – to the social reference frame that stimulates the development of their human qualities and reason, then our technogenic civilization will develop much faster, more confidently, and more sustainably.

To achieve prosperity at all civilizational levels, our priority should be life in a society of humanity, spirituality, and morality, not the desire to become a slave of the rapidly created dead, soulless, and impersonal artificial intelligence, which will control our bodies and souls based on primitive binary and virtual mathematical codes. There is no need for "rose-colored illusions" as to why this is happening – with the aim of obtaining huge profits for those who are promoting this very vector of civilizational development.

It is known that where the bow of the ship is turned, the ship will sail along that course. The state should be focused on the development of morality, spirituality, and humanity in people. Then it will be assessed upon indications featuring the level and quality of human relations. Accordingly, the work of all public institutions in the world community will be refocused on improving these indicators.

Today, heads of state are like principals of trendy schools who assess the situation only by the level of technical improvements in their educational institutions. Notably, the educational process itself at school is factored out. But what are, in fact, children taught? And are they taught anything necessary, important, and useful? What is the use of the fact that the school is equipped with the latest technology and looks good on the outside if the pupils there, oblivious of their lessons, ferociously fight with one another and "class on class", and can, in the heat of the moment, even kill each other. This is what is happening now everywhere on our planet, divided, like a patchwork quilt, between 245 nation states and dependent territories.

The level of development of people of reason, morality, and responsibility determines the quality of their relationship. Therefore, a state should not be assessed by the GDP growth rate, as is common in the age of full-fledged capitalism, but by such factors as the crime level, corruption; depression, stress, conflicts; domestic violence, mental and other diseases, divorces, abortions, suicides; the number of unemployed and homeless people; the number of single-parent or incomplete families and children raised by step parents; the number of old people left without the support of their own children.

Among the positive factors: birth rate and the level of education and morality; the number of registered family unions and orderly families, the number of gold and diamond weddings; the number of healthy (physically, morally, and spiritually) people leading a healthy and moral lifestyle; an increase in the expectancy and quality of life of each person and society as a whole; attitude towards friends and family and the outside world; the amount of preserved and augmented biosphere resources.

The main task of the education system will be fostering children's lofty qualities and pursuance of moral and spiritual development. Cinema, television, and mass media should not advertise "chewing gum and popcorn" for the prosperity of yet another business, but spread something more elevated and significant: morality and ethics, co-creation and a culture of communication aimed at strengthening the family and encouraging people to show their best human qualities in all structures of society – from the family to the state and civilization as a whole.

Now society is focused on profit, and this develops individualism and the "take it" vector in people, while commitment to the ideology of morality and humanity develops in people the will to share something important and worthy with others. Resetting humanity to the moral vector of development will entail economic growth, because where people care for each other's welfare, security and stability will rise, labor efficiency and productivity will increase, while living and operating costs and expenses will drop.

The criterion of efficiency and the level of civilization of society and an individual will not be profit, but common good, which will turn the techno-consumer humanity to socio-technocratic one. Labor will become the main element of creation and creativity rather than a mechanism for a person to survive in society, and civilization to survive on the planet.

Such a course of development can bring the world community during the 21st century to harmony and prosperity at all levels of life, without reducing population and without deindustrialization, because it was engineering technologies that increased the quality and standard of life: from the primitive level of existence of cave man to the modern civilizational level – with the simultaneous growth of a small population of two-legged and upright walking semi-animal individuals to billions of reasoned and spiritual individuals.

Owing to the rapid development of engineering technologies (against the backdrop of underdeveloped moral and ideological platforms), human civilization has entered a regime of turbulence and instability. Attempts to create new totalitarian socio-political and economic-technocratic global international systems will inevitably arise on the ruins of old philosophies and ideologies. To prevent these attempts, one needs to be aware of their symptoms.

These destructive systems block and suppress development of morality and manifestation of humanity in people, they do not allow us to find, reveal, and realize the amplitude of our human qualities. Limitation of the human reason development is conducted via social and educational stratification and limitation of knowledge, which includes reducing it to piecewise knowledge.

For example, some children are given knowledge "on bolts and nuts", others – "on vegetables and fruits", the others – on "artificial intelligence", but they are not given a kick-off amplitude of knowledge about all the diversity of the surrounding world. Moreover, the very education system is perverted: children are taught only how to become consumers and lay people, rather than social personalities and creators.

Deterioration of morality begins in childhood and is implemented by focusing people's consciousness on bodily needs. Spiritual needs mainly come down to entertainment and virtual games, most of them being trivial and primitive "shooters" in which you need to wipe out as much and many of something and someone as possible, or destroy and kill

in the most sophisticated manner. This, from early childhood, forms a person's individualism and consumer attitude to life, to each other, to the entire Universe as a whole, leading ultimately to the disintegration of individuals, societies, countries, to environmental and man-made disasters, economic and socio-political crises.

The destruction of traditional morals, which has formed in society over millennia, occurs, inter alia, through the destruction of the institution of the traditional family, as well as through the deprivation of parental rights and committing children to the care of a depersonalized and soulless state, or third-party or alien and strange individuals and organizations.

People's responsibility is blocked through the stratification of society, through the systemic subordination of people to the hastily created impersonal, asexual, and dead artificial intelligence, as well as through restriction of social rights and freedoms of the human person, which has a nature-given living body, life-creating gender, and living soul.

The planetary consumer society – a contemporary technogenic civilization – created over the last 200 years of capitalism (starting with the George Stephenson railway) now resembles reasonless mold in a Petri dish, which, having devoured limited resources and polluted a limited space with its waste, inevitably perishes.

Responsibility can develop in every person only in the space of freedom. The less genuine freedom a person has, i.e., the more quasi-protective masks he puts on his face, the more vaccines and microchips he receives, the more often he hides in lockdowns, the less responsible and unfree he becomes, step by step turning into a cyborg.

A hindrance to the development of the individuality of each person is also the one-size-fits-all approach to the assessment of the usefulness of his work for society, which, for example, was the case in the late Soviet Union – the same level of income for all employees, regardless of the volume or existence of the profit they may bring.

Another type of formidable barriers to the discovery of the talents inherent in each person are all types of stratification of society with the absence of personal means of social mobility.

In order for the artificial intelligence not to turn humanity into an obedient herd of zombified slaves, a social and moral transformation of the technogenic vector of development of our civilization is required, which translates into the progress of human relations, progress of morality, ethics, and humanity in people. And all this must be spiritually realized in order for the Earth's humanity to become a civilization of reasonable people.

It is necessary to start such a civilizational reboot with specific steps: with the construction of the first targeted projects on a fundamentally new planetary eco-infrastructure – string-rail "second level" transport, linear eco-cities at the first level, and relict solar eco-biofuel power plants, whose industrial waste will be living fertile humus and, accordingly, apples and grapes.

Proximity to the earth in a linear city would enable one to return to the origins – to Live Nature, whose part one forms and from which one was cut off, having believed in the idol of scientific and technological progress.

At birth, we receive a body – this is the only thing that will definitely be at our disposal until the end of our days. Therefore, we must love our body so that it should serve us as long as possible. It is known that we are what we eat: food is the main raw materials for the construction of cells, organs, systems, and the whole organism in general. It is also known that there is a sound mind in a sound body, and that we all study all our lives in a school called "Life on Planet Earth". The linear pedestrian city, harmoniously blended with the Earth's nature, is an ideal place for such studies. Here it will become possible:

- to walk barefoot on the healing morning dew every day and get up at the crack of dawn;
- not to fear for the lives of one's children playing on the grass, not asphalt – they will not get run over because there are no cars;
- to eat only natural organic food, which is healing and gives us (starting from early childhood, with mother's milk) health, well-being, endurance, high efficiency, and longevity. Such natural food strengthens the immune system and prolongs our life up to 100 years or more, and it cannot

be replaced by any of the most innovative and expensive biologically active dietary supplements (BADS), medicines, vaccines, inoculations, and procedures;

• to breathe freely clean life-giving air, replete with phytoncides of healing field and forest flowers, herbs and trees;

• to drink living spring (artesian) water, properly sourced from the required deep aquifer within one's own or neighboring residential cluster without deterioration of its properties and quality;

• in one's house or next to it, in one's own or a neighboring cluster to have one's favorite occupation, so there should be no need to spend hours of precious spare time on uncomfortable, unsafe, and not free-of-charge transport to get to work and back home every day. Walking to work and on other matters, while being free of charge, will become the norm – after all, based on physiology, it is advisable to walk at least 10,000 steps every day to invigorate the whole body. Such health-promoting physical treatment is beneficial at any age and has practically no contraindications;

• to communicate with Live Nature and work hard, strengthening the body and spirit, indispensable for our body, which consists of many moving elements (850 muscles, 208 bones, and 360 joints). Such daily useful physical activity on one's own land, not in the gym, is vital for us, above all for the lymphatic system, which is the internal environment of the body and is the basis of our immunity and health. Lymph consists of intercellular fluid and is the "gullet", "water pipe", and "sewerage" for every cell of our body. This liquid does not have a heart of its own, therefore, constant contraction of every single of our muscles has been evolutionally involved in its circulation through the lymphatic capillaries (without the formation of zones of stagnation in all of the above moving elements of the human body and the diseases it causes, including cancer);

• each resident will get his/her main life profession in a linear city – being a happy person, which means becoming truly rich by creating in themselves the greatest human values: health (physical, spiritual, and moral), longevity, and soul profusion.

Clusters of linear cities will become the basic platform for self-organization of communities for survival in the conditions of today's fierce global competition with a decrease in the role and importance of state borders as some kind of socio-economic regulators.

Psychologically, a person always strives to find support and mutual understanding among a community of people close to him/her in spirit and the way of life – it is not enough to feel oneself just a member of society and a citizen of one's country. A modern person, tired of constant pressure from the authorities, politicians, businesses, and advertising, vitally needs a kind of safety valve: understanding and solidarity, involvement without reaping benefits and gaining profits, self-fulfillment, spiritual, and moral guidelines. The common culture and language are also very important: the mother tongue, through which the experience and knowledge of previous generations, culture and social reference points are transmitted; and the communicatory (non-native) language, which is spoken by and between billions of people on our planet.

Such social needs – socio-cultural ties, common values, religion, traditions, art, ethnic and interethnic contacts, etc. – are satisfied precisely in small groups with similar interests. Such self-governing communities of various types, manifesting themselves in various respects (spiritual, religious, socio-economic, ethnic, organizational, and managerial, communicative, political, educational, historical, and ecological, etc.), can be created in clusters of linear cities.

At the same time, the development of science, culture, and education, small and medium businesses, tourism and the service sector, intellectual and spiritual development, upbringing of children, communicating with nature, growing organic food for oneself and members of one's family, and other areas of intellectual, spiritual, and physical activity will become the main work for many residents of linear cities.

Such work will be more interesting and more significant for any society, including humanity as a whole, than, for example, today's work as a coalminer, a lathe operator, a welder, a steel worker, or a truck driver, and it will be much better paid. Therefore, unemployment and poverty will become a thing of the past when the bulk of humanity will move from the concrete-asphalt jungles of megacities, torn from nature and life, to pedestrian linear cities, harmoniously blended with the Live Nature.

An innovative strategy for the transition of local (cluster) societies of techno-consumers to a brand-new state – a socio-technogenic society – will prevail here. Such a readjustment of the long-term development vector of the Earth's human civilization assumes conversion of military-industrial complexes and creation of a new planetary eco-infrastructure – residential, transport, production (including agricultural), energy, and information. It will become possible to use social resources of the territories, the spiritual and intellectual potential of each person, energy and resource saving technologies, in particular, through the transition from the global export of resources and raw materials to the eco-production of goods and services (from the very same raw materials) in the clusters of linear cities – backed by our own strength, interregional interaction, and the human dimension in ecology.

Conclusions and Future Lines of Research

The above analysis shows that all future humanity – about 10 bln people, and, if necessary, many times more – can live comfortably and safely on our planet. To do this, it is necessary to re-examine the attitude towards Earth's biosphere and industrial resources, engineering technologies, agriculture, transport, power industry, residential and industrial infrastructure, and, in general, towards the human personality, society, and our Earth's technogenic civilization as a whole. It is also necessary in the near future (by the middle of the 21st century) to make a resource revolution – to begin large-scale industrialization of near space.

Only the replacement of the existing global road transport infrastructure with the innovative uNet network based on Unitsky String Transport will provide real, not proclamatory, saving in the 21st century (only due to the high-speed component of this network) of [2]:

- steel – 250 bln tons;
- reinforced concrete – 3 tln tons;
- non-renewable mineral raw materials – more than 3 tln tons;
- soil (including fertile soil) – 1 tln tons;
- fuel – 40 bln tons (annually);
- atmospheric oxygen – 120 bln tons (annually);
- environmental resource – the absence of annual emissions into the biosphere of about 400 bln tons of solid and gaseous industrial waste, including exhaust and flue gases.

The cost of these saved resources is about 1,000 tln USD. Not smaller will be the value of hundreds of millions of lives saved in the 21st century (people and animals) and one million square kilometers of land occupied today by the "first level" roads, which will be returned to the original land user – the biosphere of the planet. It is also important that there are 400 bln tons of fuel combustion products and man-made pollution in the biosphere.

A civilization based on reason is able to wisely dispose of limited Earth resources. It is also able to find solutions to transfer the industry from the living biosphere into dead space, by managing to carry out this mission before the point of civilizational no return, when it will be too late to change something. This will make it possible to open the Earth's "civilizational Petri dish" and gain access to unlimited resources of the Universe – spatial, raw materials, energy, and technological.

To implement this EcoSpace program, one has to carry out all R&D activities and implement in practice the above points of rebooting the world economy to the biospheric path of development by the middle of the 21st century – before the point of no return for the Earth's technogenic civilization. Otherwise, a program that can save humanity from extinction and death will become another utopia, told as a joke (although most likely they will not have such a genre of communication) in one hundred years' time by the artificial intelligence to cyborgs living in underground bunkers on a planet turned into a desert – after all, a machine-human hybrid and artificial intelligence do not need a biosphere.

But we, people, are obliged to have time to save the living planet that gave birth to us. After all, we have two more generations ahead – this is enough time to wake up and realize that only the biospheric path of sustainable development of technogenic civilization in the logic "Earth is for life. Space is for industry" is the only right one.

The capacity of the world market in the proposed program of rebooting the world economy to the biospheric path of development will amount to more than 10,000 tln USD in the 21st century. There are seven main areas of such a reboot:

1) construction of ecological housing in linear cities, including infrastructure, for 10 bln people;

2) annual production of billions of tons of organic agricultural products in all clusters of linear cities without exception;

3) creation of the relict solar bioenergy network based on brown coal, shale, peat, wood, and any other organic energy raw materials, assuming at least 5 kW of installed energy capacity for each inhabitant of the planet;

4) construction of about 10 mln km of the uNet transport and infrastructure network, including safe, high-speed, affordable, efficient, and environmentally friendly "second level" roads, combined with electrical and information networks;

5) annual production of billions of tons of living highly fertile humus from the waste of relict solar bioenergy and organic waste generated in linear cities;

6) increasing the natural fertility of soils and improving their biogeocenoses on tens of millions of square kilometers of the Earth's land;

7) eradicating deserts on all continents and transformation of the home planet, which gave birth to and raised our civilization, into a blooming garden planted on rich chernozem.

The implementation of such a program would enable the world economy to develop steadily with an annual GDP growth of 10 % and a population of 10 bln people over the next 100 years. By that time, the entire environmentally hazardous part of the Earth's industry will be reformed and taken into near space, where it will be able to sustainably develop, for the benefit of terrestrial civilization, in our material Universe – infinitely in Time in infinite Space with infinite Resources.

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UDC 124.5

A New Shift in Values and the Establishment of Transplanetary Axiology

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The problems of the crisis of spiritual and moral values of man and humanity as a whole are considered. The importance of their reassessment at the current stage of the development of the Earth's technogenic human civilization is substantiated. The history of the problematics is shown and the mechanisms of the genesis of values described in philosophy are demonstrated. The criteria that axiological attitudes should meet are proposed in order to be able to provide a way out of the systemic crisis, set a spiritual basis, and determine the direction of development of our civilization, as well as the subsequent transition to a qualitatively new level of its existence in the oncoming historical era. It was ascertained that new values can be based only on the assertion of the need for large-scale peaceful expansion into space of the industrial technosphere created by the Earth's technogenic civilization, formed in its modern configuration only due to previous engineering (industrial) technologies.

Keywords:
values, reappraisal of values, the will to power, the will to live, civilizational goals, transplanetary axiology, industrialization of space, expansion of humankind into space.

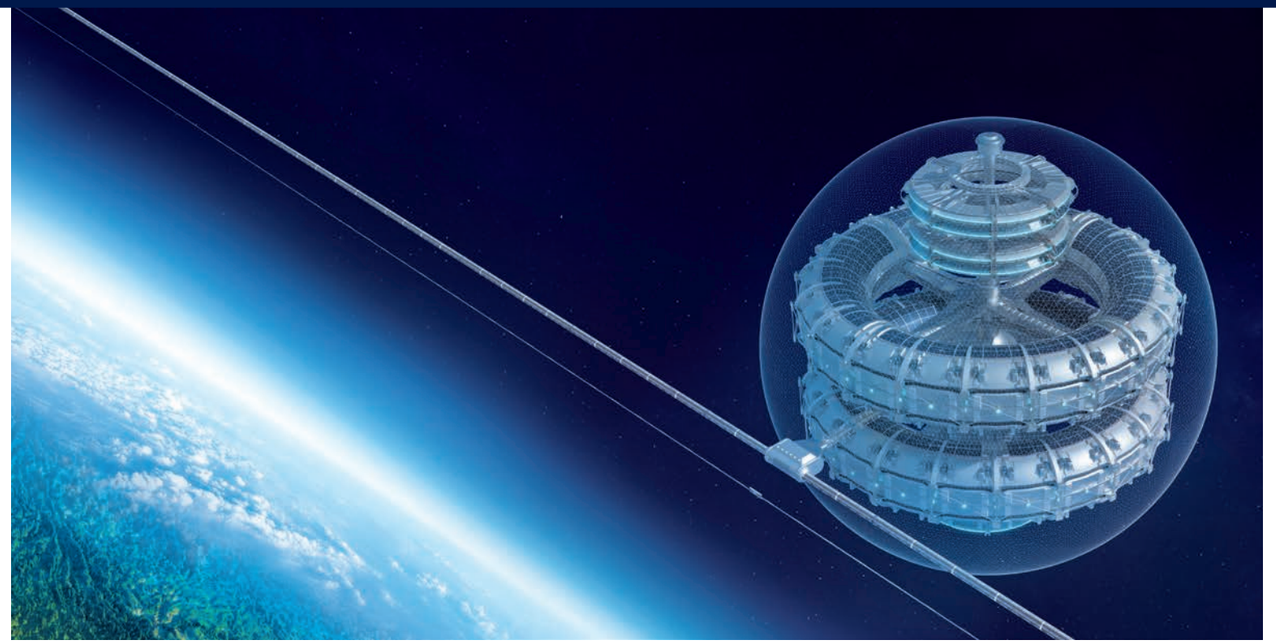
Introduction

The events of the last decade are unique, and in particular the pandemic of 2019–2021, when people were afraid to leave home. The world has always been changing, and at no time was it possible to enter the same river twice, but now, obviously, some kind of epochal transformation is taking place. K. Schwab, one of the ideologists of the "brave new world" global offensive against humanity, spoke very frankly about the upcoming socio-moral transformation of humanity, "The worldwide crisis triggered by the coronavirus pandemic has no parallel in modern history... It is plunging our world in its entirety and each of us individually into the most challenging times we've faced in generations. It is our defining moment – we will be dealing with its fallout for years, and many things will change forever... A new world will emerge" [1].

We are witnessing a historical breakthrough to which society has been moving for a long time and for which the thing that happened before our eyes was the trigger. Long before COVID-19, Professor at the University of Munich and the London School of Economics U. Beck wrote that as in the 19th century modernization destroyed the structure of feudal society and gave birth to industrial society, today modernization destroys industrial society, and another modernity is being born. We are witnessing not the end, but the beginning of modernity – that is, the modernity beyond its classical industrial structure [2].

From the U. Beck's point of view, issues related to risks and their prevention come out in the first place in the current situation. The ideal of a new society, taking shape based on this perspective, stipulates stability, security. On the one hand, this indicates the availability of a serious danger (primarily global environmental). On the other hand, it exposes the essence of the crisis that arises at the moment of social transgression and consists in the inability of humanity to be guided by positive values, to speak, think, and act in a certain horizon of a "positive" image of the future, and not only try to save and preserve what is available at present in the face of the oncoming apocalypse of human dehumanization.

In all the diversity of difficulties facing the society, we, apparently, have to talk about the crisis of values first of all. If we look broadly, the COVID-19 has brought to the fore precisely this problem, but not the issues related to medicine, economics, or politics, although many changes were noted in these areas too. However, everyone was primarily concerned about the transformations taking place at the level of constitutional human rights, individual and social freedoms, responsibility, lifestyle, way of life, habits. That is, everything



that somehow relates to the value component of the life of an individual and the society. Accordingly, since we are talking about some kind of transformation, then first it should be implemented as a reassessment of values. Moreover, if at the current transition stage, we are talking about risks on a global scale, the goals that will be set by the new values should be equally global and even cosmic in nature.

According to the authors, these values can only be based on the assertion of the need for a large-scale peaceful expansion of humankind into space. More precisely, the transfer into space of the industrial technosphere created by the Earth's technogenic civilization, since it was the technosphere based on dead anti-biospheric engineering technologies that entered into a struggle for resources with its antagonist – the living biosphere. It caused all the global problems of our time. Humanity, due to its small relative biological mass (less than 0.005 % of the mass of the living matter in the biosphere) does not pose any threat to it, like other types of living organisms (plants, animals, or insects). From these positions, for example, populations of Scots pine, cod, or flies, whose weight share in the biosphere is much higher than that of 7.9 bln people, should pose a greater "danger" to the biosphere. After all, like the human population, they participate in metabolic biospheric processes, feed from the environment, and release organic and inorganic waste of their metabolism into it.

Along with this, the technogenic civilization (i.e., modern humanity), which has arisen since the invention of the bonfire and stone tools, exists today and will develop in the future only thanks to the basic value based on millions of engineering technologies united by a common concept – industry. Unlike, for example, the dolphin civilization, which has neither science and art, nor energy and transport, nor cities and infrastructure, nor other achievements built on engineering technologies, the further existence of modern humanity is unthinkable without the industry that gave birth to it. The fact has become quite obvious: the industry has almost reached the limits of its growth due to the limited terrestrial resources – spatial, energy, raw materials, environmental. At the same time, it is well known that any resources have no limits beyond the borders of our Blue Planet – in the infinite outer space.

This article is intended to reinforce the thesis about the need for peaceful expansion of the industrial technosphere into space as a foundation for the development of new values. To do so, the authors have analyzed the current situation in the field under consideration, and also described the history of the problem. Further, on the basis of this, we have specified the criteria that new values should meet in order to be able to provide a way out of the crisis, set the spiritual principles and direction of civilization development, and subsequent transition to a qualitatively new way of its existence in the oncoming historical era and the approval of appropriate moral and ideological foundations.

The Concept "Value" and Role of Values in the Development of Society

"Value is a term used in philosophy and sociology to indicate the human, social, and cultural significance of certain objects and phenomena, referring to the world of due, purposeful, semantic basis, Absolute. Values set up one of the possible limits of a person's socio-cultural activity" [3]. Based on this, we can say that it is values that will determine the nature and direction of the movement of society and culture in the future, as they also determined them in the past.

It is quite obvious that any speculative construction, including value as a spiritual concept, is not capable of becoming a reality if you do not define a goal setting, upon reaching which it should find its material embodiment. When defining a general goal and a set of goals (a tree of goals), many philosophical questions immediately arise. At what speed is it necessary to move towards it – to walk steadily, run fast, or, perhaps, barely crawl? Is it necessary for each person to move to the chosen landmark individually or, perhaps, together with his family, relatives, and friends? And if all together in their own society, with thousands and even millions of strangers, since social values seem to us more self-sufficient and verified than individual personal ones? Or is it necessary to consolidate the entire humanity as a single species of biological organisms under the common name *Homo sapiens*? Or should the tree of goals be set up in front of our entire technogenic civilization, deeply rooted in the common industrial foundation, as a planetary structure representing a set of local, regional, country-based, and continental societies that exist only thanks to the technological capabilities of all earthly humanity?

A huge number of questions can be asked, and even more answers need to be given to them. It is obvious that each individual becomes a person only in society, and his humanness depends not so much on the personal scale of values, as on the society itself in which he was born, grew up, and was brought up, having absorbed fundamental values with his mother's milk. Undoubtedly including the following: both values and life goals, for example, those of Mowgli, fed by wolves, or Indians, raised by a tribe, or Europeans, whose origins sprang in Ancient Greece and Ancient Rome, Russians, who had their roots in paganism, will be completely disparate.

Since the values and goals of each society are different, the problems that arise during their implementation will also be radically different. That is why the proposed solutions for achieving the set goals cannot be the same – they are opposite and even antagonistic. At the same time,

the logical chain being built "basic values → set goals → → emerging problems → balanced solutions proposed to settle problems" will have a completely different orientation, boundaries of implementation and time length, depending on a particular society.

Since our terrestrial technogenic civilization as a whole (as a combination of all societies, as a megasocium consisting of 7.9 bln individuals living in 195 independent states, nine states with an uncertain status, 38 dependent territories, three territories with a special status, 16 territories without permanent population, 22 territories of states considered an integral part of them, but belonging to another part of the world, and two territories disputed by several states) is at the top of all social structures of humankind, then by itself it should become the greatest value for every person. At the same time, the general civilizational values of this megasocium should be only biospheric, since our civilization was born, grew up, and turned out to be "registered" with billions of other species of living beings in our common house (or rather, in a large room that has no windows, doors, or even partitions) – in the biosphere of planet Earth.

Ultimately, the issue of the humankind's survival, which has arisen against the background of global environmental problems characteristic of our time, is an issue of certain values that drive us all. At the same time, the technological equipment of a technogenic civilization functioning on the planet as a global technology consumer will play an incomparably smaller role than the intangible civilizational components – social, moral, ideological, and spiritual aspects. No technical devices or ideas aimed at rationalizing people's lives, protection of the environment, and well-being will be implemented if there are no corresponding socio-spiritual values in the society.

On the other hand (for example, from the standpoint of Marxism), the appearance of certain values is due to the specifics of the relations between people into which they enter during the production, exchange, distribution, and consumption of the social product. However, this does not make the role and importance of values in the life of society any less. Yes, a change in technical equipment can contribute to a change in values. Yes, values are secondary, but they are what ultimately make humanity change. As N. Berdyaev wrote, Marxism was not only the teaching of historical or economic materialism about the complete dependence of man on the economy, Marxism was also the teaching about deliverance, about the messianic vocation of the proletariat, about the upcoming perfect society in which man would no longer depend on the economy, about the power and victory of man over the irrational forces of nature and society [4].

Consequently, it is obvious that even a Marxist, deeply deterministic approach acknowledged the predominant role of values in the processes of social transformation. N. Berdyaev's statement should be understood just in this sense: Marx's materialism turns into extreme idealism [4]. It is natural, therefore, that both the ecological crisis of modernity and the crisis of the image of the future, characteristic of our days, are somehow connected with the crisis of values. This crisis is not the first of its kind, but under certain conditions it may well prove fatal for our civilization.

The modern world, which intensive formation began with the age of Enlightenment and the scientific and technological revolution, has experienced a number of crises of values. The most general view gives the following picture. First, the denial of the values of traditional cultures based on religion. Then there is the denial of the values of technological progress due to upset with the consequences to which this progress has led. Next – departure from the values offered within the framework of three ideologies of the 20th century and their corresponding systems: nationalism (including fascism), socialism (including communism), capitalism in various versions of its existence. At the same time, in reality, the latter model (capitalist) still retains its position and dominates the world. However, it is experiencing a prolonged depression, primarily noticeable on the leveling of the value system inherent in capitalism.

Initiative, entrepreneurship, success, wealth, competition, free market – all this began to look very dubious against the background of environmental and social problems that result from the behavioral mindsets arising from this. But in reality, humanity is unable to generate anything fundamentally different, equally massive and attractive. As a result, the value structure of civilization, its sociosphere, acquires a relative character. There are all kinds of surrogates and mixes that combine elements of political, religious, scientific, and ideological doctrines. Axiologically, everything is presented as relative, situational, acquiring meaning only in the context of a particular discourse.

The society is deprived of values other than those that relate to the lowest material level of consumption. "I am what I possess and what I consume" [5]. This is how E. Fromm, author of the term "consumer society", described the current situation. In fact, such a society is inert, since it does not have a goal set by the values that the majority shares. So, it doesn't have a future either. The people in it, as E. Fromm noted, are just "eternal babies, hungry for nipples" [5].

The things that today's degrading capitalist liberal world offers to replace values, including inclusivity, confirms the above. The relativity of all values is put forward for the role of the highest value. Consequently, the requirements of tolerance and equality in all forms of its manifestation become determining for the development of society. Thus, equality is indicated between the guiding principles of opposing ideological doctrines, religions, social, and gender groups, cultures, traditions, i.e., the nature of what is happening corresponds to the formula "everything equals everything". Obviously, such mindsets cannot act as "the ultimate limits of socio-cultural activity" [1]. The horizon of the activity they set and the goals they dictate will, in fact, be focused on nothing more than preserving the status quo. No orientation, no transformations, no qualitative development is possible here – constructive, creative, interactive, coevolutionary, because humanity should not only change nature but is also obliged to change itself, adapting to this nature. Probably, it would be not bad. However, only if we lived in an ideal, absolutely prosperous world, which is absolutely not the case.

Against the background of environmental, political, social, spiritual, and other problems, on the solution of which the survival of man as a species depends, modern values (more precisely, anti-values, since they devalue everything) resemble a sleepwalker, completely disconnected from life. Suddenly waking up (which sooner or later happens), he does not understand the situation he is in. Or, without waking up, he dies, falling into the abyss, never realizing at the moment of his fall what really happened to him.

Yes, it can be stated with sufficient reason that in this universal relativity, as in the point of view on the world, the attitude to nature is also being revised. The ideas of equality of all species of living beings are postulated, an ecological imperative is established, setting the creation of a carbon neutrality economy (net zero) as a goal. However, all this is nothing more than a call to achieve the most stable state of the capitalist system and the society of material consumption, but not civilization as a whole. At the same time, such a system of universal consumption, which has recently taken a tilt in the direction of virtual emotional consumption, including through the step-by-step transformation of a biological person into a digital cyborg, is initially imperfect in its fundamental parameters. Thus, the possibility of achieving the desired stability is highly questionable. And in general, such concepts as "value", "goal", "achievement", "problem", "solution", cease to be adequate to the situation. The words "business plan", "task", "execution", "optimization" will be more appropriate here.

The values of society should not only provide conditions for preservation, they are also needed as a horizon of growth. If this is not the case, then we are no longer talking about "value", but about "cost", which, apparently, is inherently closer for capitalism, including inclusive capitalism advancing on humanity. In order to explain what has been said, it is necessary to look even deeper into the history of the issue.

Genealogy of Values

It should be noted that the problem of values in philosophy, and in the life of society as a whole, has come to the fore quite recently. For Antiquity and the Middle Ages, this topic was incurious. At that time, people's worldview was made up in the system of religious coordinates, focusing on the corresponding goals, priorities, and prospects. Values are something else. People start thinking about them when the medieval traditional culture dies out. It can be claimed that the problem of values arises in a situation of devaluation of former values and their reassessment.

This process was analyzed most fully and deeply by F. Nietzsche. For example, one can recall his idea of the "death of God" – someone or something should take the place of the departed Absolute. M. Heidegger gave a brilliant interpretation of the teachings by F. Nietzsche. Explaining, he added a lot of new things. The texts of two German thinkers present the fundamentals of everything that is necessary to know about values in order to understand who or what shapes them; what they have to serve to; what kind they have to be in order to fulfill the role of God who has left the world, allowing humanity to continue "the path to light" in his absence.

To put it very simply, the value according to the judgments by F. Nietzsche is the point of view, i.e., the point at which the eye of the beholder is located and from which his attitude to the world is projected. At the same time, the value as a point of view always means a condition of preservation and growth [6]. It has a dual nature due to the fact that this is the nature of life itself, of which value should be a part. F. Nietzsche defined this essence as the will to power, which drives everything in the world, including man. If this will weakens, if the value does not reflect its dual essence and does not allow the power to surpass itself at every moment, to grow, then the being led by such values begins inevitably to degrade and rushes to its death.

Despite the apparent complexity of such a mental construction, its meaning is simple and clear. The thing that ceases to grow and develop, dies. This is happening today in liberal culture with its pseudo-values that make everything relative, thereby depriving society of even the possibility of choosing the direction of development. Here is an example for illustration: in order to get to a certain place located in the north, you need to know where north and south, east and west are, so that there is the very possibility of moving in the right direction. If you start to reason and act in the way that south and north, east and west are relative, then in the end it will turn out that there is no need and nowhere to go; you just need to lie down and die, because life and death are also relative.

Values, according to F. Nietzsche, are a point of view precisely because they (unlike the external Absolute) should originate from a person and be set by him as a carrier and manifestation of the will to power. A person here, acting as a fundamental condition, is obliged to realize his own "value" [7]. No matter how strange it may seem, but today *Homo sapiens* is not actually considered as a "value". Although the opposite is widely claimed. However, only in form. The essence is correctly noted by Professor O. Garanina, who wrote that anthropological centrism, expressed in the dominance of humanistic values, strife for the affirmation of life and signifying the biophilic life-value orientation of a person, is being replaced by technical and informational utilitarianism, which does not require direct human contact, depriving a person of emotional intimacy and spiritual mutual enrichment. In the structure of the modern anthropogenic world, technogenic elements are gaining dominant importance, as a result of which the value of living structures is leveled out. The space of natural life narrows under the pressure of artificial, technical objects, in communication with which kindness, mercy, and compassion are not required [8].

In this context, the following is extremely important: the basis of the assumption of values, according to F. Nietzsche, is the structure of the will to power. Only in this way the established values lead to survival, because life through the will to power lies in their very essence. Without this, any values, and, in particular, modern pseudo-values, not only turn out to be unviable by themselves but also lead to the destruction of the society that is guided by them.

It should be further clarified that the Nietzschean concept "the will to power" implies something much deeper than the desire of some people to dominate others with the help of force, politics, etc. "The will to power says that the Existence "is present", that is, something through what it dominates (as power)" [7]. This is a kind of internal driving force of all living things, something that was at the heart of the Big Bang, and something that makes a blade of grass grow through the earth, fighting for a place under the sun with other existing things. Close to this concept is the key concept of another famous German philosopher A. Schopenhauer "the will to live", by which he understood the aggregation of "blind and irresistible" desires that form the essence of our individuality: it is them who ensure the reproduction of individuals and the continuation of the genus [9]. The values that give life are assigned to stand on this basis.

Humankind and every person must strive to overcome, gain a victory, be stronger, but not act as proposed in the modern world of liberal structures: to understand and forgive, to live without any goals, without procreation (this way of behavior is indirectly called for by the ideals and goals of human existence imposed by liberalism), without understanding of oneself and society as an intermediate entity on the path to perfection – something that will always need to be surpassed, but not equalize and talk about the relativity of everything and everyone.

Since values are conditioned by man and humanity, which are carriers and manifestations of the will to power and the will to live, no values can be final, the process of their assumption and depreciation is continuous and occurs as once accepted virtual values cease to be applicable to the real world. In this case, the world itself becomes devalued [7]. It is obvious that this is the situation of world depreciation that we are witnessing today.

Tolerance, equality, lack of spirituality, relativity, rights of animals, ecological imperative – all this, perhaps, provides conditions for conservation, but does not provide space for growth. Consequently, such values are simply inapplicable to the world of man-made civilization (which differs, for example, from the purely biological civilization of dolphins) with all its contradictions and problems – primarily environmental ones caused by the technosphere. Once again: values ceased to be applicable to the world, and the world itself began to seem devalued. The assumption of new values, the overcoming of nihilism is necessary in this situation as a condition for the survival of humanity – one of the billions of species of living organisms inhabiting the planet.

Each species of organisms has its own niche in the biosphere, and only *Homo sapiens* occupied all these niches at the same time through the technosphere he created. He occupied it not as a living organism, but as a technological environment surrounding it, hostile to all living things. For the biosphere, any human-made mechanism, machine or factory is, in fact, an alien cancer cell, with which its immune system, perfected by billions of years of evolution, is simply obliged to fight. A car that has "rolled" fertile soil into asphalt and is poisoning everything around with exhaust gases is part of the aboveground technological environment; the plow, chemical fertilizers and pesticides introduced into the fertile soil and leading to its widespread degradation are part of the underground technological environment; the launch vehicle delivering a communications satellite into orbit, destroying millions of tons of ozone along the way, and making ozone holes the size of Belarus is also part of the technosphere, occupying a niche of air and near-Earth space.

Reassessment of All Values and Criteria for the Introduction of New Axiological Foundations of Society

Explaining one of the key points of F. Nietzsche's teaching, M. Heidegger considered that the reassessment of all previous values should be carried out and approved on the basis

of the maximum awareness of one's own consciousness of the value essence and the assertion of values [7]. The value essence of man and humanity is determined, as already mentioned, through the will to power. The essence of values is the provision of conditions for preservation and growth. Thus, having briefly considered the history of the issue and describing the present state of things, we can systematize the general conditions and requirements for values that need to be approved and comprehended today:

- applicability to the modern world, adequacy to the real state of things, problems, and opportunities;
- affirmation of the priority of human life and fundamental freedoms (as a carrier and manifestation of the universal will to power, rather than, for example, as a carrier of the attributes of a particular social or sexual minority);
- consolidation of everything created by civilization during the previous millennia up to the present time and ensuring the preservation of the achieved level in the material and spiritual spheres of social life;
- designation of directions and opportunities for further comprehensive material (man-made) and social (spiritual) development.

Proceeding from the above requirements and looking at the issue from the standpoint of all humankind, which has entered the turbulent global stage of its existence on the planet long ago, when the interests and actions of some countries and nations are closely intertwined with all others, the approval of new values should also be conducted on a planetary scale. Only such an approach can be adequate to the global problems we are facing. If we accept the second point from the above list of criteria and agree that only a person can be put as the basis for the assumption of values and only as a subject of the will to power, then there can be no question of limiting him in this in any way. And finally, if a person should not be limited in his essence and at the same time should have a horizon of development, this opens up to us only in the outer space. Therefore, the new values should have a transplanetary nature.

Affirmation of New Values: Transplanetary Axiology

Since new values should meet the specified criteria, their development must be considered in a broad historical context. The basic axiological mindsets were transformed and developed in the logic of their increasing abstractness and universality. On the ground of the ethnographic material available today, it can be assumed that the primitive society was guided by interests, goals, and guidelines that reflected the tasks of increasing the power of the tribe, community, and clan. In the Ancient era, values serving the tasks of the state come to the fore, which is clearly seen in the example of Ancient Rome, which is characterized by the ideals of citizenship. With the emergence and spread of world religions, man becomes subordinate not to the community and society, but to God. Values acquire a supranational character. Then the age of Enlightenment postulates the regulation being developed to this day that an individual can depend only on nature, comprehended through the laws of science, and on legal laws established through rational knowledge. This is the basis of the idea of universal equality, and then the liberal program of the individual's liberation from any types of collective identity (national, political, religious, sexual, up to the proclamation of human freedom from being human, because this is also a kind of collective identity). At each stage, the transition from one axiological paradigm to another occurred through a reassessment of values. Similar processes can be observed at the present time, and the general logic of development suggests that the next step on this path will also be taken as a new stage of generalization. The existing trends confirm the theoretical conclusion, testifying to the formation of the transplanetary axiology.

As it was already noted, the basis of the formation of values is the requirement of adequacy to the existing problems and opportunities of civilization. Consequently, the emergence of new basic mindsets is largely determined by the dangers that society faces in one or another period of its development. At first, it is nature, hostile and incomprehensible. Then, these are neighboring states and tribes threatening to attack and destroy. Then, in the period of the emergence of Christianity, Buddhism, and Islam, powerful centralized states with a rigid hierarchy, leaving no space for freedom for the ordinary person, turn out to be such a danger. In order to compensate for external circumstances, people turned to the inner spiritual dimension, where they found an outlet for their desires and aspirations. However, the increasing formalization and power ambitions of clerical institutions themselves become a threat over time. Bonfires and tortures of the Inquisition, various taxes and restrictions. Science and rational law become the way to a new liberation. The development of science and the industry generated by it is a new danger. Environmental and demographic threats are determining in today's world. An effective way to solve them opens only through passing beyond the planet

into the outer space or the destruction of the threat itself – the industry that cannot be waste-free in principle, which means it will continue to pollute and poison the environment until the end, until it makes it uninhabitable (it does not matter – a little later or a little earlier). However, the rejection of the industry or its substantial reduction is equal to self-destruction for civilization. That is why only the outer space remains.

The large-scale exit of humanity beyond the boundaries of the planet, and not as one of the biological species of living organisms, but as the only species that embarked on the technological path of development and created a technosphere that covered the entire planet, allows us to provide opportunities for further growth and development in the aspects of the will to power and the will to live. The essence of these things is very simple – all living beings tend to grow above others and above themselves. Accordingly, the absolutely consistent desire and task of humanity is to grow beyond the limits of the Earth, which, according to K. Tsiolkovsky, is our cradle, but it is impossible to live in it forever, just as it is impossible to stay forever in a crib [10]. Otherwise, we will follow the fate of mold in a Petri dish: having exhausted all limited resources and polluting a limited space with the waste of its vital activity, it dies as a population.

Colonization of the outer space, its large-scale industrialization, transition to a new stage and level of civilizational development – these should be the highest values of the modern world. Let other values start from this fundamental postulate and reinforce it. The greatest elaboration of this direction of axiological thinking was received in the works of representatives of the scientific school "InoMir" ("Engineer of the New World") headed by engineer A. Unitsky. In particular, within the framework of the doctrine of the impossibility of resolving antagonism within the boundaries of the same planet between the biosphere created by nature and the technosphere created by a technogenic civilization [11–13].

"The technosphere occupies the same ecological niche as the biosphere on the whole: machinery, mechanisms, technological devices are located in the depth of the earth, water, air and are actively exchanging energy and materials with them. Ecological problems rose sharply in the last quarter of the 20th century for the reason that the technosphere approached the biosphere in terms of its power supply capacity, i.e., by its ability to transform the environment...

There is only one drastic way out of the current situation: it is necessary to provide the technosphere with an ecological niche beyond the biosphere. This will ensure preservation and development of the biosphere in accordance with the laws and directions that have been formed during billions of years of evolution, as well as a harmonious interaction of a people's community as biological objects with the biosphere.

There is no such an ecological niche for the technosphere on the Earth. However, it is found in space, where the majority of technological processes can have ideal conditions: zero gravity, vacuum, ultra-high and cryogenic temperatures, indefinite raw, energy, and spatial resources, etc.

Thus, we have come to the conclusion on the need for space industrialization if the terrestrial civilization continues the path of technological development in the future. Humanity does not have much time for a large-scale space exploration since its irreversible degradation along with the degradation of the human race will start, according to a number of forecasts, in two-three generations due to a technocratic oppression on the biosphere" [11].

Global environmental problems on the planet, in principle, cannot be eliminated without the industrialization of space due to the antagonistic contradictions between biological technologies of metabolism of wildlife and engineering technologies of metabolism of the dead technosphere. At the same time, the solution of environmental problems, of course, should become the main goal of modernity and substantiate a new system of values in such a format.

It is extremely important that such a point of view sets the direction for solving problems, i.e., creates a positive vector of development. In contrast, today the negative modus is taken as the basis for the formation of values (more precisely, their substitution). It is not so much about the need to find a radical way out of the situation, as about maintaining the health of nature within certain norms, etc. Such a pathological state of a social system affected by nihilism should be corrected through a reassessment of values in the logic of the transplanetary axiology.

Instead of powerless and lifeless structures of equality and tolerance, it is necessary to affirm the values of the unity of humanity's goals, within which everyone is equal not just in terms of their political, sexual, and other preferences, but in the sense of involvement in a common cause – one for all humankind and a particular person, in whose nature the main principle of the existence of any living organism is originally laid down: procreation. "I, as a living organism, should not become the last point in the evolution of life," – this is the sense of every life.

Instead of conducting a virtual pseudo-struggle for the rights of animals and asserting virtual pseudo-equality with them, it is necessary to start real work on cleansing the planet, on which both people and animals will be able to live in normal natural conditions, equivalent for all, in accordance with the life niches created by the nature. The life of an animal cannot be placed above the life of a person, and vice versa: they must be equal in their rights, since they are members of the same family – the biosphere, born by a common mother named Planet Earth. However, this does not mean that a person cannot eat animals, since natural food chains were evolutionarily created in the biosphere by nature itself, and not by man. That is why we should not fight with nature here, but accept what it has laid down in us, people.

Instead of the ecological imperative and the desire to minimize carbon emissions (and at the same time, inevitably, to reduce industrial production and carry out deindustrialization), we need to set ourselves the opposite goal: to increase the industrial power of civilization by an order of magnitude, while making sure that it does not harm our common civilizational home – terrestrial nature. It is not necessary to protect an animal by lowering *Homo sapiens* on all fours to its level, it is necessary to allow the animal to remain so in its natural habitat, removing from the planet the cancer of the biosphere created by man-made civilization – the technosphere.

Conclusion

The study of the history of axiological issues and its current state in the aspect of the ongoing transformation and reassessment of values allows us to determine the criteria according to which it is necessary to search for new basic mindsets of the spiritual dimension of society. These include the adequacy of the existing state of things, the obligation to assert the priority of life and fundamental human freedoms, ensuring the preservation of the achieved level in the material and spiritual spheres of social life, creating conditions for further positive development.

These factors assume the preservation of the industrial orientation of our Earth's technogenic civilization while simultaneously shaping the requirements for reducing the technogenic load on the biosphere, which arose billions of years before the appearance of man on the planet and, accordingly, the technosphere. Obviously, this will be possible only with large-scale space exploration for industrial purposes.

The rejection of outlined goals is equivalent to a ban on walking upright, which, as is known, has brought people a number of physiological problems over the past hundreds of thousands of years. So why not help the "imperfect" *Homo sapiens* to get rid of them? Why not "improve" a person? And such a ban will be quite adequate to the request of some ideologists for the creation of a "brave new world" to return to "their origins" within the next few decades. In fact, a person is now being compelled in every possible way ("for his own good") to start walking on all fours again. After all, such a vital principle (four pillars instead of two) is physiologically more stable, which is indisputable. Although, which is also quite predictable, it is unlikely that as a result of such a transformation, a person will turn out to be sociologically and spiritually closer and clearer, for example, to a dog or a cat, whom he will simply have to love more than himself in the "brave new world".

The space vector of development (quite real thanks to machinery, as well as within the framework of the technology of the General Planetary Vehicle (GPV) capable of delivering up to 10 mln tons of cargo and 10 mln passengers to the equatorial orbit in one flight environmentally friendly), designed in the form of an appropriate value system, will become a powerful tool for consolidating society [12]. After the era of spiritual awakening, united by the doctrines of world religions, after the time of great unrest and globalization, marked by the conflict and fusion of the ideologies of nationalism, communism, and capitalism, a new era will come in which a new man will triumph. Superman. The one whose arrival was foreseen by F. Nietzsche, but in such a guise that the philosopher could not have imagined. It will be a cosmic superman and a cosmic superhumankind.

The development of research on the subject of the assertion of new values and the formation of transplanetary axiology implies further a more thorough analysis of the conceptual core of A. Unitsky's philosophical system, analysis of the continuity of key concepts in relation to the philosophical tradition, and systematization of the views of representatives of the school "InoMir" on the main sections of philosophical knowledge: ontology, epistemology, axiology, ethics, aesthetics, philosophy of history, philosophy of science, and social philosophy.

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UDC 711.424

Linear Architectural Model as a Solution to Civilizational and Urban Deadlocks

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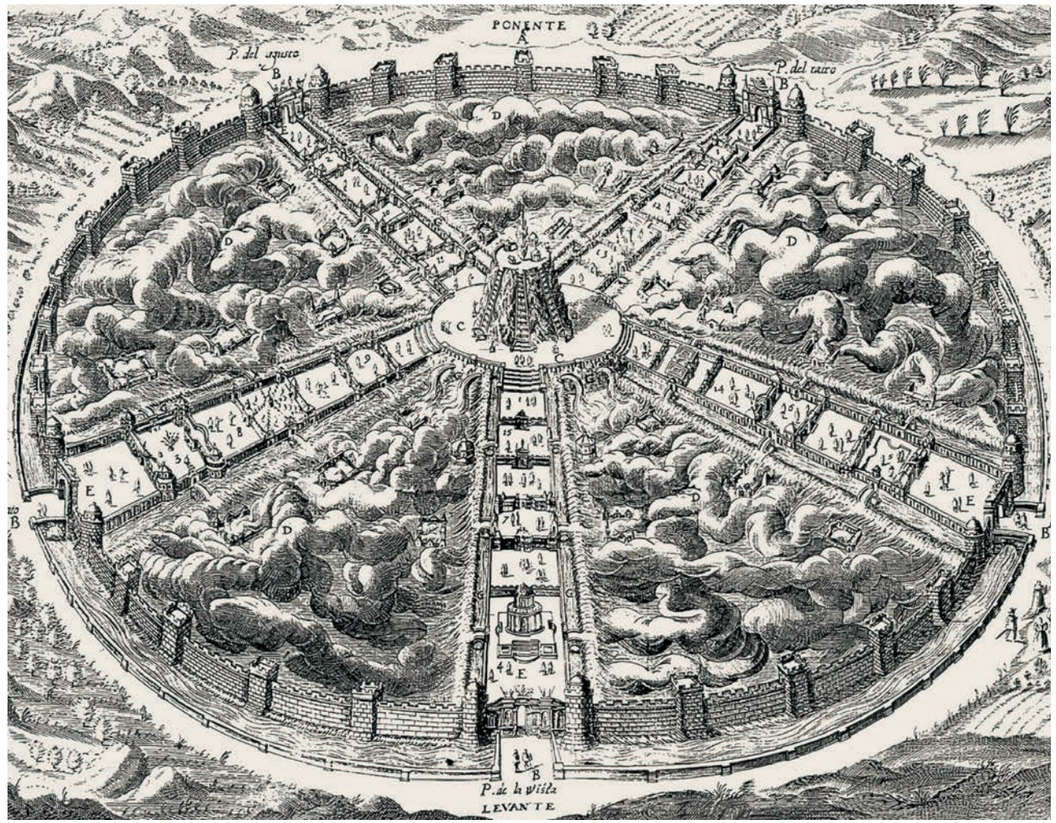
Genesis of architectural model of an ideal settlement in different historic periods was considered. Achievements and drawbacks of the given examples of urban layouts were outlined. The need to continue searching for new settlement systems was highlighted in order to work out the idea of linear city. The problem of organizing linear settlements was proposed to be studied in immediate relation to the development of high-speed transport and "second level" transport systems.

Keywords:
ideal city, smart cities, linear settlement, residential cluster, "second level" transport systems.



Introduction

Growth and development of urban localities is the guiding idea of the evolution of human civilization. It is complicated to determine the shape of urban layout, which is due to a range of factors: geolocation of settlement; economic and political feasibility of emergence; physical, social, and aesthetic value of erected objects.

For centuries we have seen a strong demand on creating a comfortable place of residence that is extremely adapted to environmental conditions and protected against various threats. The evidence of this fact is the cities and towns described in literature. They are depicted in projects or already exist and fit perfectly to the given parameters (i.e., ideal cities) [1].

The material proposed below demonstrates that the authors of different urban planning concepts saw that reasonable societal organization can develop the harmonious structural model of settlements and the ways to achieve the common good. The material part of such harmony was actualized in spatial and layout look of the cities.

In times of growing interdependence between countries and nations, there is an urgent need to build livable places as a condition for ensuring equal development for all. This article highlights positive parameters of novel settlements which satisfy this requirement.

Analysis of Stages in Creation of Ideal Settlements

The Earth's civilization evolved by building cities. Originally, a city meant an enclosed place (walled or ramparted). The original idea of the city was to defend against outer and hostile world. Such way of settling provided a whole range of other advantages: the cities served as craft centers and places for scientific and artistic boom.

In addition, cities were nodes of technical achievements; the main trade routes passed through them. Urban planning developed into a separate discipline studying laws and rules of settlement organization.

As any art, urban planning aims at perfection. A strong desire of architects to create an ideal place which would satisfy various demands of society can be traced during a long time [1, 2]. The degree of perfectness is determined by how a specific individual or a group of people imagine it.

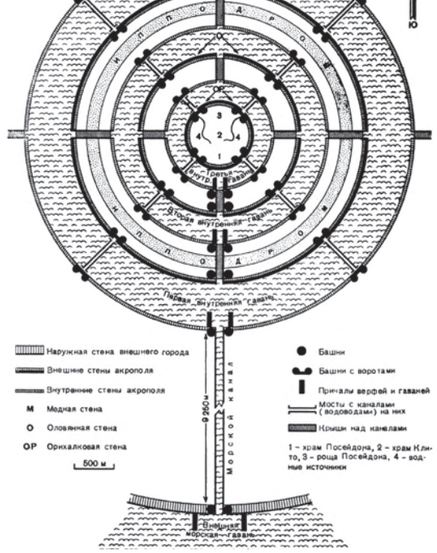
Plans of many cities demonstrate that their designers followed different requirements. In a sense, some of the interests were satisfied (whether it is a possibility of effective all-round fire when defending a walled city, or meeting the demands of community in a utopian city), and the other were only dreamt of and imagined by the authors. They never found the final response to the demand for an ideal settlement. Modern large cities are now stuck in crisis, which manifests itself in transport collapses, deteriorated environment, and deficit of territories for further development. For a long time, they have been focused on satellite towns as a possible way out. However, this concept cannot solve the problem: when joining to nearby cities, such satellites become megacities.

Humanity will manage to escape the urban crisis when all achievements and drawbacks of the past are studied and considered. The examples given in the analysis of the development of the ideal city concept (Table) do not reflect the entire experience acquired by city designers, but illustrate their images of a harmoniously arranged world. Urban planning ideas demonstrate the ordering of space in contrast to the chaotic world. The walled city, which is separated and protected against enemies, gradually transforms into a centralized garden city surrounded by nature.

It should be noted that this article considers both imaginary utopian cities and implemented projects. The Table gives the analysis of planning solutions for various settlements from the ancient times to the present day.

Table – Analysis of the development of the ideal city concept

Atlantis city, 4th century BC
Concept author: Plato (427–347 BC) [1–5]; Figure: [3]



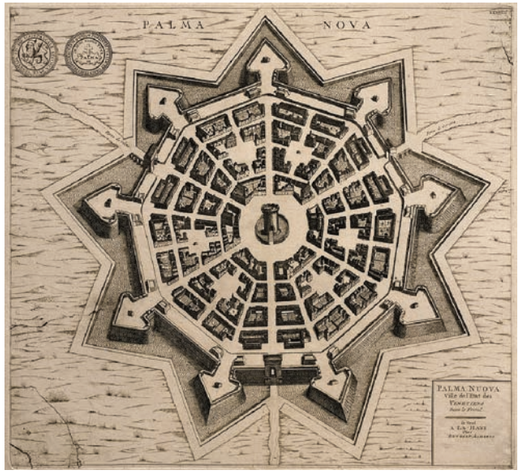
Features:
- location on an imaginary island;
- temple and palace of the king are located in the downtown;
- ring-type layout (two reinforced ground rings and two water rings, as well as radial roads stretching from the center);
- welfare and flourishing of the city are connected with the way of organizing harmonious public relations inside the city as opposed to chaos outside its borders

Achievements:
- protection against enemies;
- compact plan ensures land saving;
- optimization of connections as a result of functional organization of the territory;
- regular provision of the city with food due to compact distribution of fields and farms around the perimeter;
- harmonious relations among residents

Drawbacks:
- imperfect human nature is not considered;
- centralized control of two upper societal classes (ruling philosophers and warriors) turned out unable to preserve stability of the system;
- no urban space prospects, which limits opportunities for growth and development

Continuation of Table

Fortress cities, 1st century BC – 16th century AD
Concept authors: builders of Ancient Rome and Renaissance (1st century BC – 16th century AD) [1, 5].
Concept author of the fortress city of Palmanova: Vincenzo Scamozzi (1548–1616); Figure: [6]

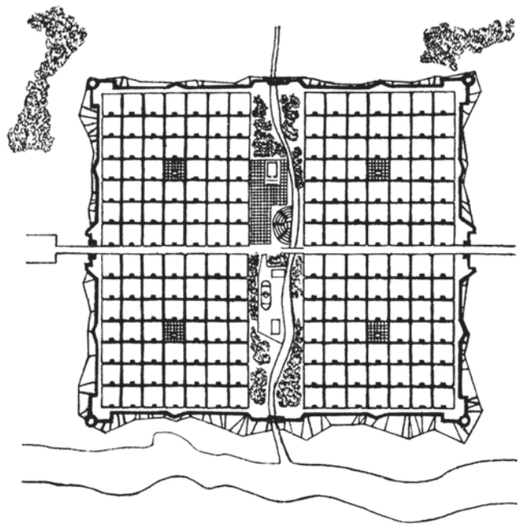


Features:
- the town of Palmanova shown in the illustration is located in northeastern Italy;
- has clearly defined boundaries;
- distinguishes by its compact size;
- characterized by a symmetrical building system;
- regular shape as a nine-pointed star solves defense problems;
- fortress cities (star-shaped towns) are characteristic of the Renaissance period

Achievements:
- optimal usage of internal space;
- ease of orientation;
- geometry of the plan reflects public mindset

Drawbacks:
- more convenient for war than peaceful life;
- insufficiency of greenery;
- weak life-support system;
- unattractive for business

Amaurote (Utopia), 16th century
Concept author: Thomas More (1478–1535) [4, 7]; Figure: [8]



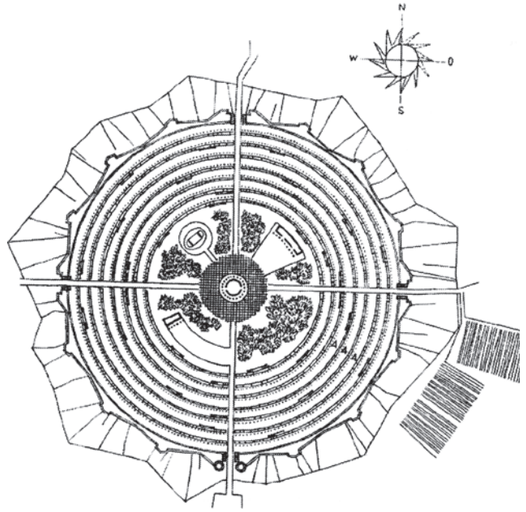
Features:
- location on an imaginary island;
- city plan – 3 × 3 km square;
- quarters – 200 × 200 m;
- each house has a garden;
- green urban space (green park space, river);
- ramparts with towers around the city

Achievements:
- ease of orientation;
- regular planning;
- protection against outer world;
- each house has a garden;
- planted urban space;
- arrangement of public places, parks, availability of river

Drawbacks:
- resembles more of a war camp than a place for everyday life;
- only residential quarters, no space for manufacturers;
- impossibility of further settlement planning development

Continuation of Table

City of the Sun (Italy), 16th century
Concept author: Tommaso Campanella (1568–1639) [4, 6]; Figure: [6]

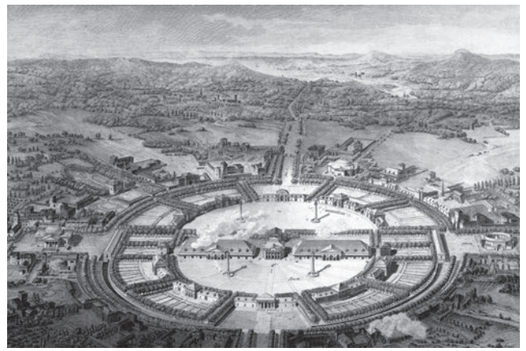


Features:
- theocratic city-state with supreme ruler Sun (Metaphysician);
- concentric outline;
- location – an imaginary island near the equator on a mounting (hill);
- temple and king's palace on the central square surrounded by a park;
- circular terraced layout, involving seven ring belts separated by fortress walls, and radial roads passing from the center;
- no private property, everything is common

Achievements:
- compact size;
- functional organization of the plan;
- a good example of hostile terrain development;
- elements of fantasies are blended with facts of life

Drawbacks:
- only residential quarters, no place for manufacturers;
- impossibility of further development

City of Chaux (France), 18th century
Concept author: Claude-Nicolas Ledoux (1736–1806) [5, 9]; Figure: [6]

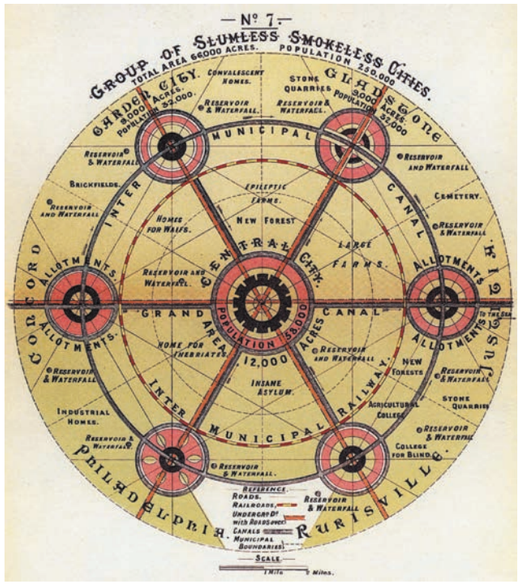


Features:
- industrial space is willfully combined with worker's houses;
- the central square is occupied with main public buildings;
- streets extend as radial beams and are landscaped by trees;
- green ring mains;
- free space in all directions around the building without frontages;
- nearby nature inflows perfectly into the city limits

Achievements:
- environment is no longer hostile and becomes part of the life of citizens;
- optimal alternation of residential and industrial spaces;
- equally favorable living conditions in the city and village

Drawbacks:
- ideal city was never built;
- close relation to current technologies makes construction senseless before it is even completed

Garden City (England), 20th century
Concept author: Ebenezer Howard (1850–1928) [6, 10]; Figure: [6]

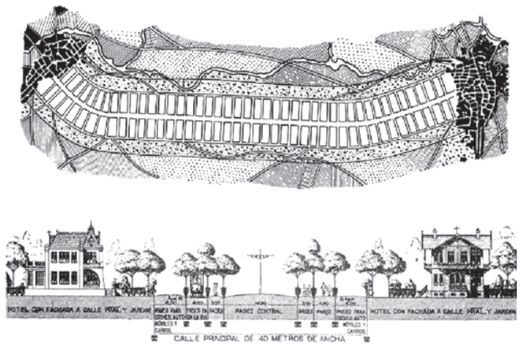


Features:
- compact size;
- belt zoning;
- built on non-agricultural land;
- green (park) center which concentrates main administrative, trading, and cultural buildings;
- streets and boulevards are planned in radial rings and developed by living quarters with cottages;
- radius of the residential area is approximately 1 km;
- agricultural areas and industry are located in the periphery;
- some cities are grouped together with common center

Achievements:
- equal and free-willing participation of each citizen in the management of the city social body;
- idea of the city encouraged the movement on organization of distant self-sufficient cooperative settlements (tenants' associations) which can solve the housing problem of the poor;
- suggestion of construction beyond the territory of established cities drastically decreased the cost of land and allowed complex erection of service infrastructure and engineering communications;
- simplified regulation of the number of population and size of territory, normalizing the size of land lots, as well as easy control over their rational use;
- all facilities are within a walking distance;
- later on, a similar idea was actualized in different urban projects of the 20th century

Drawbacks:
- the idea was implemented in different countries but nobody managed to make the full of it;
- transport network in such settlements becomes significant so they should have considered the immediate participation of public bodies in the development of the settlement system;
- the idea requires large-scale social and political transformations to be fully embodied;
- erection of settlements in different countries was initiated mostly by large private industrial companies which sought to improve the life of their workers;
- the social essence of this endeavor disappears when the activities condominiums are interfered by authorities or building initiators, as well as by the land owner and investor (industrial company)

Linear city (Spain), 20th century
Concept author: Arturo Soria y Mata (1844–1920) [5, 11]; Figure: [11]

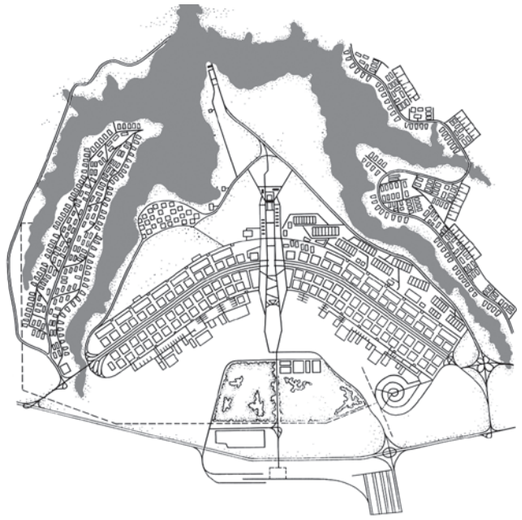


Features:
- project implementation – 1894–1910;
- the city for 30,000 people;
- built in the suburbs of Madrid in form of a narrow belt along the tram-line;
- transit-oriented city;
- transport network is formed of the main highway of 40–100 m in width and cross streets of 20–40 m in width;
- buildings are up to three stories tall

Achievements:
- transport type defines the shape of the city;
- reduction in travel time;
- ease of orientation;
- absence of downtown equalizes the cost of land throughout the entire city;
- easier access to nature;
- a house per each family and a garden per each house;
- space for development of urban structure

Drawbacks:
- the length of the city extends communications and makes public facilities less accessible within a walking distance;
- remoteness from workplaces;
- unattractive environment to locate workplaces;
- suggestion of linear city contradicts to the concept of the city itself

Brasilia city (Brazil), 20th century
Concept authors: Lucio Costa (1902–1998), Oscar Niemeyer (1907–2012) [12]; Figure: [12]



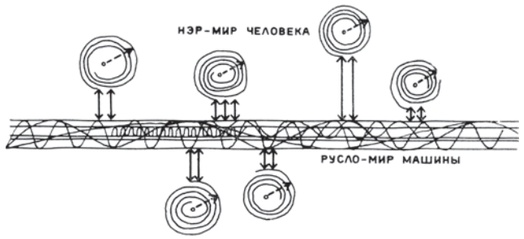
Features:
- new capital of Brazil;
- built in 1960;
- linear city idea is observed;
- location on Brazil plateau at a height of 1,050–1,200 m above sea level;
- UNESCO World Heritage Site;
- original plan assumed 500,000 residents with equal living conditions

Achievements:
- build strictly according to plan;
- clear functional zoning;
- much free green space;
- residential area is almost free from road traffic (there is clean air and silence);
- equal living conditions are planned for all citizens

Drawbacks:
- only 400,000 people of over 2.5 mln citizens of Brasilia live in the planned city due to high housing prices;
- foreigners make up more than half of the population;
- the city is planned for cars;
- pedestrian links are too extensive and there is a lot of "dead" space

End of Table

NER (New Element of Settlement) in the system of linear city (Russia), 20th century
Concept authors: Alexei Gutnov, Ilya Lezhava, et al. (NER Group) [13–15]; Figure: [15]



Features:
- NER is a cluster and a unique self-sustained unit in the settlement system;
- the settlement layout is based on transport and communication channels;
- established centers are connected with the new structure;
- significantly shortened distances due to high-speed transportation

Achievements:
- solution to overpopulated large cities;
- elimination of transport collapse in megacities;
- significant environmental improvement. The human – nature relations become friendly;
- formation of resource-saving economy;
- new-quality comfort of living

Drawbacks:
- absence of high-speed linear transport makes the idea impossible to implement;
- available ways to organize manufacturing require a drastic transformation;
- insufficient working out of social changes and ways to transit from established state system to the new ways of self-government

The above review reveals positive parameters of the future city [16]:

- living in a spacious and comfortable house;
- provision of increased safety;
- human-friendly environment;
- residents define the way to govern the settlement;
- sufficient amount of social facilities (schools, kindergartens, medical institutions, etc.);
- continuous development and improvement of the transport system;
- comfortable living conditions for the groups of population with various needs and preferences.

In addition, based on the analysis of concepts, there have been identified dead-end directions that should be taken into account in the future in order to avoid them:

- absence of high-speed linear transport as a structural basis for the settlement system;
- absence of "second level" transport systems which vacate the land for pedestrians and greenery;
- imperfect social organization with prevailed centralization and poorly developed self-government;
- absence of population control mechanisms and uncontrolled growth of megacities;
- isolation from living natural resources;
- contradiction between the settlement development prospect and insufficiency of territories, as well as difficulties related to access to transportation;
- restrictions in the development of new industries and workplaces.

Consideration of the positive parameters of the future city will contribute to successful creation of settlements of new type. The authors assume that the right way is to develop the concept of linear settlement.

Linear City as a Possibility to Escape from Urban Trap

The professor of the Moscow Architectural Institute I. Lezhava claimed that one paradox of the future city is that it will never be built. He assumed that this is a horizon impossible to reach [17]. The analysis reveals that cities and agglomerations of concentric (star) type lose their relevance. Environmental and land resources in them are almost depleted, nature is being destroyed on urbanized lands, conventional planning becomes an insurmountable obstacle for transport. Every year Asia witnesses the death of 1.56 mln people from air pollution. Man-triggered climate changes make desert advance over 1/3 of the land; in 2050 it will affect 2 bln people. By 2025, 2 bln people will lack water, and by 2050 this number may grow to 3 bln people [18].

The future belongs to novel dwelling units. The idea is formulated as follows: the city is an integral and multicomponent organism, and thus a complex system. It can be studied only by subsystems which, being parts of the whole and obeying the integral system, have relative independence, internal structure, inherent markers, interests, functioning rhythms and require another language to be described. The idea of linear organization of a city became completely revolutionary in the minds of people since all previously known plans of ideal cities – circular, hexagon, radial, and regular – were different in their structure but were centric cities no matter what. The linear city became a finished urban planning idea at the end of the 19th century and remains relevant to the present day. Reasonable rethinking of the foundations and principles of linear planning will allow a drastic change of the situation in large cities and megacities, including transport problem to the extent of a whole country or continent [13, 14].

Settlements of new type have the traits of an ideal city based on the following principles [19]:

- resource-saving – self-sufficient and cyclic use of resources;
- accessibility – fair and equal access to accommodation, urban amenities, decision making, employment, healthcare, education, services, culture, business, recreation, cultural heritage, sport, and nature;
- sense of community – cooperation and unity in social interactions, exchange of skills, and encouragement of valuable social ties;
- safety – stability to climate changes, extreme weather, healthy environment, access to important resources (food, water, accommodation, etc.);
- desirability – a place pleasant and comfortable to live in where everything is planned to meet human needs with attractive public spaces for recreation, studying, etc.

The new element of settlement (residential cluster) will become the key unit of environment when connected with the "channel – city" system. It is based on the transport channel to relocate the flows of people and cargo (water, energy, natural resources, etc.). The transportation will be ensured through such channels as roads, pipelines, transporters, and rail systems. Thousands of facilities will be located in the channel with a width of 10–15 km: residential settlements, factories, educational centers, recreation spaces, and even entire cities. Along and near the channel there will appear territories of intensive land management: croplands, farms, pastures, fisheries, and forests. Many sites located away from the channel will be unpopulated; abandoned regions will return to pristine nature.

Undying concrete boxes that have been built recently will be successfully replaced by novel residential systems. The chains of hundred-thousandth cities located along the channels with new environmental living standards, proximity to nature, and dense social contacts that are characteristic of downtowns of the old cities will form the modern settlement system to attract active population [14].

Another notable trend is the transition from facade architecture and the volume of an individual building to the creation of a livable and comfortable environment. At the forefront of this concept are the tasks of forming a city with all of its technical systems working interconnectedly and stably for many decades. Such properties can be ensured in an area with clear boundaries in terms of site area and population capacity. Compactness will be an important feature of this city. Everything necessary for life will be accessible within a walking distance. The buildings will be autonomous and self-sufficient units, a kind of "house-cars for dwelling". The planning structure follows the "city-car for dwelling" pattern. Dormitory districts will become history to be replaced by the urban development complex, which gives the opportunity to live, work, rest, acquire new knowledge, do a favorite work, and enjoy nature having it all in close proximity. Connected by modern transportation systems, the layout of the cluster makes all of the above feasible. In ancient times, linear settlement of people took place along riverbeds. Modern settlement will begin to unfold along transportation channels.

The new things come today, but the old ones will long accompany them and influence the future. The task for a modern urban planner is to assimilate the experience of the past, take its achievements, and take into account the shortcomings. Professor of the University of Pennsylvania V. Rybczynski noted: "The next city will include much that is new, but to succeed it cannot ignore what came before. Linking the past with the present, and seeing the old anew, has always been part of our improvised urban condition" [20].

Linear City Based on String Transport Systems

String transport (uST) developed under the supervision of engineer A. Unitsky can create this system of transport channels – communication and infrastructure network called uNet. It serves the basis for organizing linear settlement structure – uCity (the linear city in its new interpretation), where they use eco-oriented (biosphere) technologies, as determined in the EcoSpace program [21].

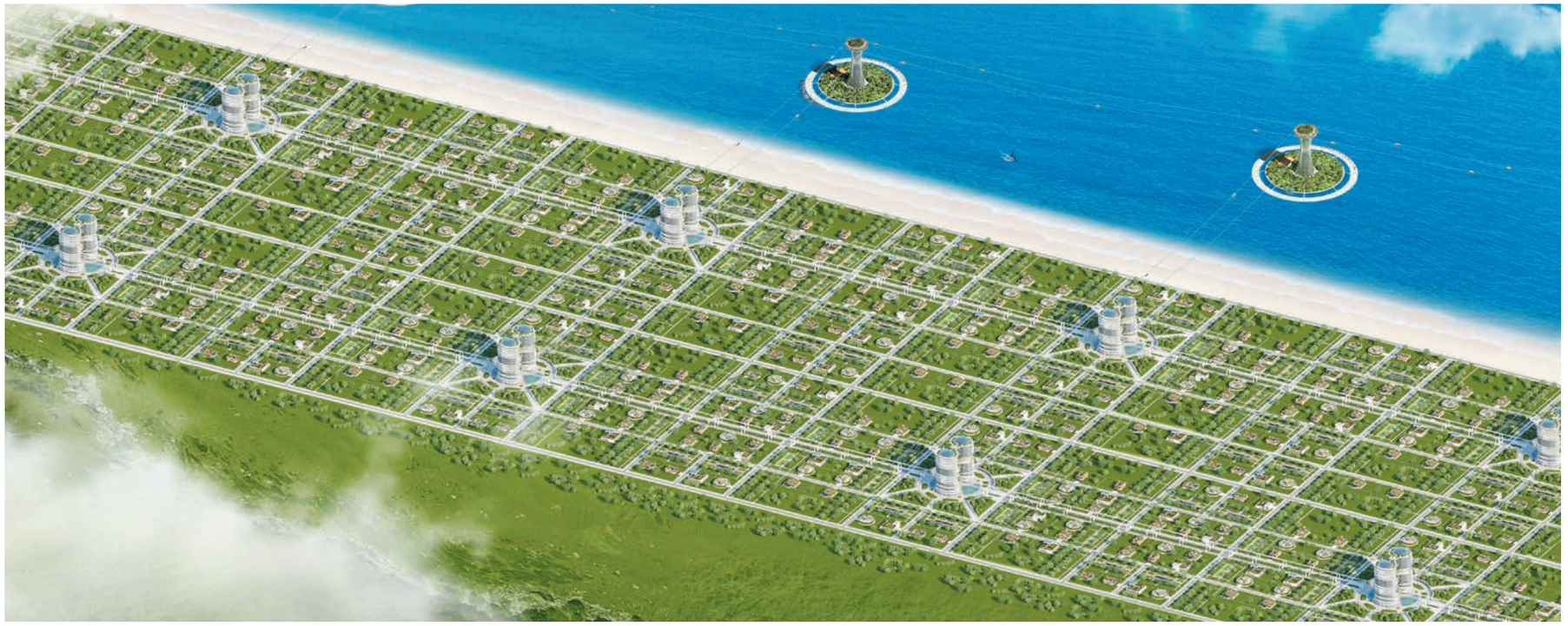
Construction of uCity is based on uST transport and infrastructure technologies and smart city logic whereby land belongs to pedestrians and greenery. The distinctive elements of uCity are multifunctional dominant buildings with integrated stations of uST transport and infrastructure complex located in each cluster. The basic planning units of such residential cluster are autonomous residential buildings – "horizontal skyscrapers" (high-rise buildings "lying on their sides") or aligned low-rise buildings with a range of engineering systems that provide the residents with everything necessary for life, including organic food, drinking water, electric and thermal energy, as well as a complete biosphere recycling of household waste.

The residential cluster will not have ground transport (apart from bicycles and light-weight electric cars); they will be replaced by "second level" uST urban transport systems that are light-weight, laced, and even casting no shadow. Their advantages include:

- low capital and operational costs of the complex;
- zero carbon emissions;
- improvement of biosphere due to the introduction of innovative agricultural technologies intended for planting of deserted territories;
- better quality of living by creating natural ecosystems of emerging cities;
- significant energy-saving, use of renewable energy;
- drastic changes in logistics and reduction in the cost of developers' projects;
- normalizing of urban infrastructure to unified quality standards;
- zeroing of the risk of mortality on urban roads [22].

Residential, industrial, educational, sport, recreational, agricultural, and other clusters are located along the transport-energy and infrastructure-information channels of the uNet as per established regional and general planetary natural and climatic conditions. The cluster is highly autonomous and can both consume and reproduce viable resources without polluting the environment. The uNet and neo-settlement system will ensure maximum natural preservation [23]. Widespread application of elevated "second level" transport systems will vacate the Earth's surface for harmonious coexistence of humans and nature. Scattered and independent life, sense of unity with nature, connection of high-speed transport and communication system to the entire world, as well as fast, comfortable, and safe travel around the planet, make up the advantages of a cluster-type linear city.

Neo-settlements are aimed at elimination of growing contradictions between biosphere and man-made medium. Man, created evolutionarily from flesh and blood, is not a competitor to nature, but its child, taking his first steps, can live in harmony with it and treat his mother nature with love. Linear settlement system based on uST transport and infrastructure communications provides such opportunities [24].



Forecast of further development of linear settlements gives the following conclusion: in the future, the key general planetary communication and infrastructure complex will be the Equatorial Linear City (ELC) extending by slightly more than 40,000 km which is built along the launch overpass of the General Planetary Vehicle (GPV). The ELC will pass along the equator across continents and oceans, i.e., across the Earth in the equator plane. The size of such settlement will exceed the size of the planet for the first time in history [24].

In turn, the GPV geocosmic complex will allow to clean the planet from man-made urban dirt – it will relocate all industrial waste of the Earth to the near space. This is possible due to unique performance and economic parameters of the giant aerial vehicle: the GPV is capable to ensure eco-friendly transportation of up to 10 mln tons of cargo and 10 mln passengers at a cost thousand times lower compared to launch vehicles.

The ELC will become the key linchpin between humanity on the Earth (about 10 bln people by that time) and servicing space industry – the Industrial Space Necklace "Orbit" (ISN "Orbit") [25]. The ISN "Orbit" will also be implemented by the linear city logic except for being on orbit with orbital prestressed string communications embracing the planet in the equator plane. It is only these communications which can ensure stable operation of this giant industrial and residential complex.

Orbital residential clusters are planned to be built as EcoCosmoHouses (ECHs) – enclosed biosphere ecosystems with the most comfortable living conditions for space settlers in terms of natural and climatic conditions similar to the Earth's subtropics [26].

Conclusion

The models of harmonious organization of life in the considered historical examples of various cities and towns suggested different ways to achieve the common good by reasonable structuring of society and interaction between its members. The material part of such harmony was actualized through spatial arrangement of cities as ideal settlements.

The analysis of achievements and drawbacks in our review enables to highlight positive parameters of the future city and apply them in new conditions. The modern civilization aims to provide access to the most remote parts of the planet, as well as to increase the speed and safety of passenger and cargo transportation. Worldwide transportation

network uNet based on string technologies by engineer A. Unitsky will lay down the basis for linear settlement system. Erection of the new linear settlements is a response to the demand for building comfortable residential spaces as a condition of equal development for everybody.

The future geocosmic linear settlements – the ELC and ISN "Orbit" – will launch the fundamentally new stage in the evolution of human population on Earth. Our multibillion man-made industrial civilization that have been developing for thousands of years will move to space, and thus receive a strong impulse in its development for the millions of years to come with a revolutionary logic: "Earth is for life. Space is for industry".

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UDC 711.416-122

Equatorial Linear City: Construction Features

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The article considers the issues regarding the organization of the linear settlement structure – the Equatorial Linear City (ELC), located along the General Planetary Vehicle (GPV) launch overpass (uWay). It identifies the equatorial zone areas, preferable for the location of the main planning elements of a linear city, considering the climate, equatorial geological line, and the existing settlement structure. It also indicates the search directions for new planning systems and describes the conditions influencing the location, functioning, and evolution of the ELC residential clusters. It proposes to analyze the organization of the linear type development aggregated with "second level" transport systems and indicates the relevance of an integrated approach.

Keywords:
smart cities, equatorial climate, linear type of settlement, residential cluster, General Planetary Vehicle (GPV), "second level" transport systems, Equatorial Linear City (ELC), equatorial geological line.

Introduction

The future of urban settlements, due to the peculiarities of their growth over the past time, is alarming and prompts the search for acceptable solutions in the urbanized environment planning. In the 20th century, experts in urban studies indicated that the urban fabric will acquire an increasingly clearly expressed discrete organization, since the self-sufficiency and internal completeness of its structural units becomes one of the defining conditions for creating a full-fledged living environment – an environment that meets the tasks of forming a harmonious personality, provides appropriate living comfort, and stimulates social activity [1].

In this article, the authors propose to pay attention to the relationship of developing urban structures with the organization of transport communications.

The mankind establishment is followed by the improvement of transport systems. Uninhabited areas are settled, discoveries are made, previously unknown resources are being developed. However, territories are finite, resources are exhaustible, and the desire for other discoveries has no limits. People invent more rational ways of settling, design and produce new types of transport. Progress in this direction has already led civilization to unacceptable technogenic interference with nature. The artificial environment displaces natural ecological systems. An unprecedented amount of industrial and domestic waste begins to exceed the adaptive capabilities of the planet [2, 3]. This situation demands taking care of the environment. Concerns about the state of the environment are reflected in international agreements (Kyoto Protocol, Paris Agreement), as well as in national legislation [4].

The contradictions between the technological progress of civilization and the established cycles of nature are growing and dictate different approaches to the organization of society, require the modern view of use, conservation, and renewal of natural resources. The reasonable distribution of the environmental burden and the introduction of waste-free production and consumption systems are the ways to resolve these contradictions.

The construction of linear cities can solve the problem of overpopulation in megacities and improve access to natural resources. By erecting houses of ecological type, it is possible to significantly reduce energy costs and exclude environmental pollution with household waste.

New generation cities – linear cities – are being developed within the EcoSpace program. To create an EcoSpace, including BioSpace, TechnoSpace, and HomoSpace, is an urgent task for obtaining acceptable conditions for sustainable growth and evolution of technogenic civilization within the Earth and in the cosmic direction [5].

The development of technology will certainly lead humanity beyond the boundaries of Earth's environment, to the large-scale exploration of near and deep space. The EcoSpace program states that this goal will be achieved by non-rocket technology through the construction and operation of the General Planetary Vehicle (GPV) and the Industrial Space Necklace "Orbit" (ISN "Orbit"). One of the main issues to be resolved in the process of the GPV implementation is organization of settlements for the appropriate resource support of the GPV. The optimal location for the GPV is the equatorial zone. As a result, the deployment of the GPV service systems is planned in the Equatorial Linear City (ELC) [6, 7].

The ELC is the terrestrial component of the geocosmic transport and communication complex, on the territory of which there is the GPV takeoff and landing overpass (uWay) with all the infrastructure necessary for carrying out flights and servicing global geocosmic cargo and passenger flows.

The ELC harmoniously fits into the natural environment of the planet's land and water areas in the form of a new type of settlement system (cluster type settlements, which are located in the equatorial zone and are interconnected by "second level" transport systems – the routes of the Unitsky String Transport (uST) [8]).

Climatic and Geographical Features of the Equatorial Zone

The ELC construction is planned directly in the equator region. Therefore, the climatic and geographical features of the area should be considered. On the one hand, the equatorial belt is characterized by ideal conditions for the life and development of residential settlements. On the other hand, and for the same reason, its areas are already intensively populated not only by people but also by numerous representatives of the animal and plant world. The ability to enter the living tissue of a complexly arranged community with a new artificial formation, without violating the delicate balance, will ultimately determine the success of the project.

The equatorial climate zone is located on both sides of the equator and has the richest ecological system on Earth. The average annual air temperature in the area of the Sunda Islands and southern part of the Philippine Islands is 24–26 °C.

The maximum temperature is 37 °C, the minimum does not fall below 17 °C. During the year 2,000–3,000 mm of precipitation falls. Air humidity does not exceed 90 % [9].

In South America, almost the entire Amazonian Lowland, the south of the Orinoco Lowland and the Guiana Highlands are located in the equatorial belt. Annual precipitation is 2,000–3,000 mm and up to 6,000 mm on the western slopes of the Andes. The air temperature is around 24–30 °C [9].

In Africa, the equatorial belt covers the Congo Basin to the eastern coast of Lake Victoria and runs in a narrow strip along the northern coast of the Gulf of Guinea. The air temperature in this area is kept at a constant level: 24–30 °C. Air humidity is 90 % or more. The amount of precipitation reaches 3,000 mm per year [9].

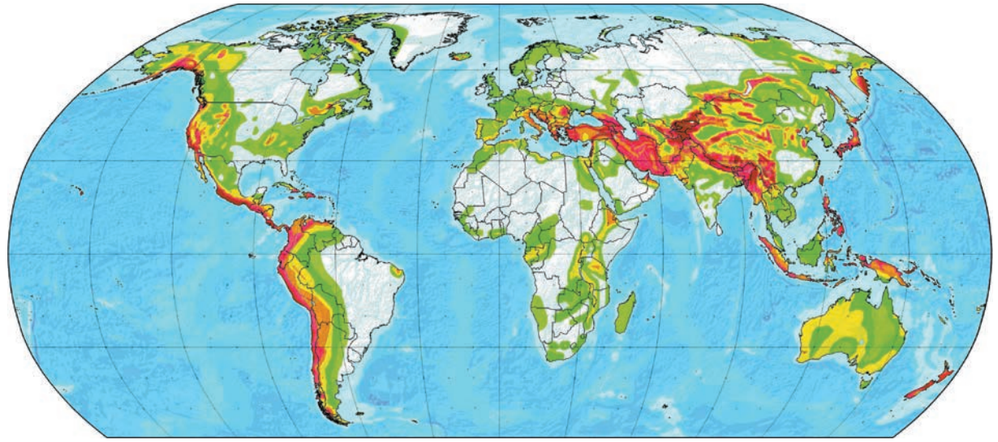
The main international geographical organizations accepted circle as the conditional form of equator, however, the relief has fluctuations within 6,000 m along the equator on the continents. The equator line runs through rain forests, high-mountain plains, crosses rocky mountain ranges, large bodies of water, and even a volcano, as well as passes through earthquake zones. Based on the results of the global seismic hazard assessment carried out under the UN auspices, an extremely accurate seismic hazard map was compiled (Figure 1).

The most active seismic zones in South America are located along the Pacific coast of the continent. In Africa, seismic activity is almost not observed in its central part. The islands of Indonesia, Fiji, and Tonga are experiencing a record number of earthquakes. Considering the length of the uWay, there is a high probability of being constantly influenced by these factors.

Atmospheric phenomena in equatorial regions are influenced by the Earth's surface and extend over the entire troposphere crust. Three (in each hemisphere) circulation elements are identified in the Earth's troposphere: the Hadley cell (equatorial latitudes), the Forell cell (temperate latitudes), and the polar cell (Figure 2). The atmosphere of the equatorial zone is formed of tropical air masses brought by the trade winds of the Northern and Southern Hemispheres with the transformation of the air towards its humidification.

The lowland part of the equatorial belt is recognized as not the best place for life. Not every person is able to withstand the conditions of rugged wet multi-tiered forests. At the same time, equatorial forests are the planet "lungs".

The climate of the upland regions of the equatorial belt is a summer with regular rains, constant sun, and warmth.



Peak acceleration of soils, m/s²
(the probability of a possible increase in the intensity of earthquakes within 50 years is 10 %)

0 0.2 0.4 0.8 1.6 2.4 3.2 4.0 4.8

Figure 1 – Seismic hazard map [10]

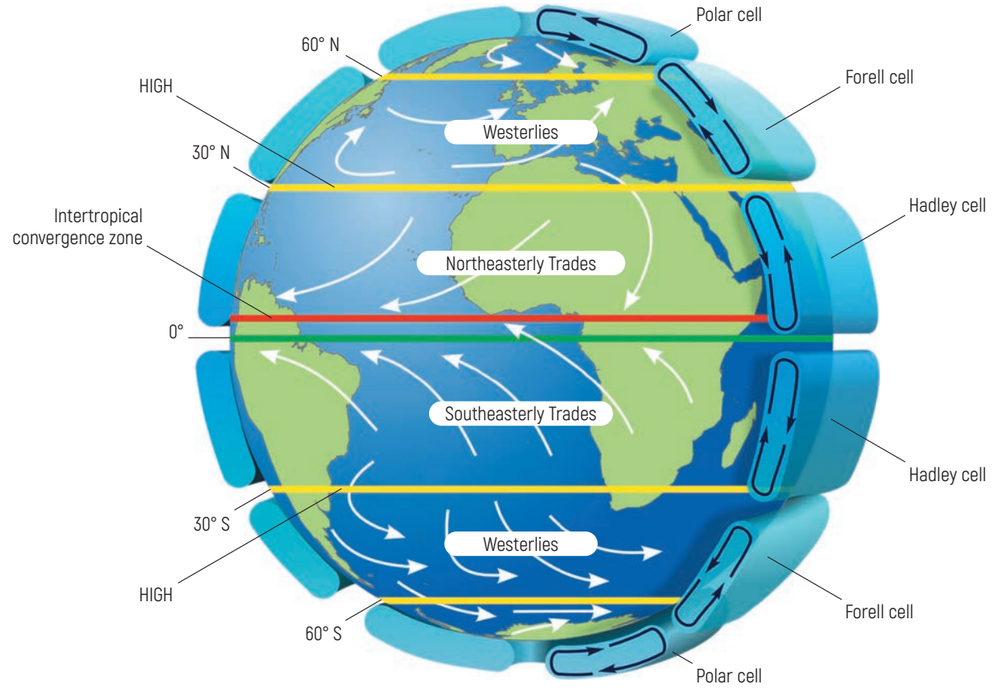


Figure 2 – Circulation cells in the troposphere [11]

The conditions are favorable for people living, and also good for agriculture (there is an opportunity to harvest twice a year) [11, 12]. Upland areas are densely populated (Figures 3–6). The equator line in the above illustrations is marked in red.

At the beginning of 2021, the population density of the equatorial belt countries was as follows (person/km^2): Somalia – 24.22; Kenya – 81.75; Uganda – 166.01; Democratic Republic of the Congo – 37.01; Congo – 15.73; Gabon – 8.12; Brazil – 24.73; Colombia – 42.27; Ecuador – 64.15; Indonesia – 140.15. At the same time, the average density of the Earth's population is 57.7 person/km^2 [12, 13].

Figure 3 – Residential buildings and farms
in the equatorial zone – Lake Solay (Kenya, Africa) [14]

Figure 4 – Equatorial zone –
Nayaeruru city (Kenya, Africa) [14]

Analyzing potential sites for the construction of the uWay and the accompanying ELC, we note that it is necessary to focus on the formulation of a precise specification describing all the requirements of the system. To do this, it is necessary to unite not only the engineers' efforts but also to attract specialists with competencies in other fields of knowledge (urbanists, ecologists, biologists, economists, sociologists, etc.).

If you go on a round-the-world trip along the equator line from the Indian Ocean coast to Somalia and continue it in a western direction, you'll pass through the countries of Africa, South America, and the islands of Indonesia along the following route shown in the Table.

Figure 5 – Equatorial zone –
San Antonio city (Ecuador, South America) [14]

Figure 6 – Equatorial zone –
Pontianak city (Indonesia, Eurasia) [14]

Table – Analysis of the route distance along the equator line, considering the relief

Geographic location	Route distance, km	Route section, km	Height above sea level, beginning, m	Height above sea level, ending, m
1	2	3	4	5
1. Africa		**4,026**		
1.1. Somalia		**211**		
1.1.1. Somalia (Indian Ocean coast – settlement)	0–24	24	0	7
1.1.2. Settlement – river	24–25	1	7	10
1.1.3. River	25–40	15	10	0
1.1.4. River – border with Kenya	40–211	171	0	89
1.2. Kenya		**780**		
1.2.1. Border with Somalia – Hagadera Refugee Camp	211–279	68	89	124
1.2.2. Hagadera Refugee Camp – Izhara	279–319	40	124	168
1.2.3. Izhara – Ailo	319–461	142	168	338
1.2.4. Ailo – Meru	461–502	41	338	378
1.2.5. Meru – Nharaka Threads	502–519	17	378	476
1.2.6. Nharaka Threads – Meru	519–556	37	476	859
1.2.7. Meru (residential area)	556–594	38	859	2,163
1.2.8. Meru (residential area) – Nanyuki	594–632	38	2,163	2,409
1.2.9. Nanyuki	632–666	34	2,409	1,817
1.2.10. Green zone	666–677	11	1,817	1,920
1.2.11. Farms	677–700	23	1,920	2,098
1.2.12. Farms – Ndogino	700–717	17	2,098	2,297
1.2.13. Ndogino – Nayaeruru (runway)	717–726	9	2,297	2,364
1.2.14. Nayaeruru (runway) – Shamenei	726–737	11	2,364	2,555
1.2.15. Shamenei – Sabekia	737–739	2	2,555	2,298
1.2.16. Sabekia – Solay	739–748	9	2,298	2,085
1.2.17. Solay – Baringo	748–749	1	2,085	2,037
1.2.18. Baringo – Mogotio	749–769	20	2,037	1,548
1.2.19. Mogotio – equator	769–807	38	1,548	2,515
1.2.20. Equator	807–829	22	2,515	2,563
1.2.21. Equator – Nandi Hills	829–871	42	2,563	1,725
1.2.22. Nandi Hills – east of Kahulu	871–897	26	1,725	1,739
1.2.23. East of Kahulu – Lake Victoria	897–991	94	1,739	1,135
1.3. Uganda		**478**		
1.3.1. Lake Victoria – untitled island	991–1,026	35	1,135	1,147
1.3.2. Untitled island	1,026–1,027	1	1,147	1,135

Continuation of Table

1	2	3	4	5
1.3.3. Lake	1,027–1,109	82	1,135	1,135
1.3.4. Untitled island	1,109–1,112	3	1,135	1,150
1.3.5. Lake	1,112–1,123	11	1,150	1,135
1.3.6. Untitled island	1,123–1,129	6	1,135	1,150
1.3.7. Untitled island – lake – shore of Lake Victoria	1,129–1,178	49	1,150	1,135
1.3.8. Shore of Lake Victoria – Kayabwe	1,178–1,206	28	1,135	1,147
1.3.9. Kayabwe – Seeta	1,206–1,216	10	1,147	1,142
1.3.10. Seeta	1,216–1,223	7	1,142	1,159
1.3.11. Seeta – Birongo	1,223–1,232	9	1,159	1,152
1.3.12. Birongo – Kibisi – Kitami	1,232–1,264	32	1,152	1,179
1.3.13. Kavanda	1,264–1,290	26	1,179	1,218
1.3.14. Ntusi	1,290–1,307	17	1,218	1,291
1.3.15. Bugologolo	1,307–1,324	17	1,291	1,245
1.3.16. Rvemikoma – Kazo	1,324–1,363	39	1,245	1,291
1.3.17. Kasozi – Lwemizimu	1,363–1,406	43	1,291	965
1.3.18. Lake George	1,406–1,424	18	915	915
1.3.19. Katoho – border with the Democratic Republic of the Congo	1,424–1,469	45	918	1,053
1.4. Democratic Republic of the Congo		**1,621**		
1.4.1. Border with Kenya – Kiondo	1,469–1,502	33	1,053	1,970
1.4.2. Kiondo – Musanen	1,502–1,524	22	1,970	1,783
1.4.3. Jungle	1,524–3,022	1,498	1,783	310
1.4.4. Mbandja	3,022–3,039	17	310	318
1.4.5. Mbandja – border with Congo	3,039–3,090	51	318	322
1.5. Congo		**426**		
1.5.1. Border with the Democratic Republic of the Congo – Makua	3,090–3,325	235	322	330
1.5.2. Makua	3,325–3,330	5	330	303
1.5.3. Jungle (Makua – border with Gabon)	3,330–3,516	186	303	539
1.6. Gabon		**510**		
1.6.1. Border with Congo – jungle – Atlantic coast	3,516–4,026	510	539	0
2. Atlantic Ocean		**6,534**		
2.1. Ocean (coast of Gabon – Sao Tome Island)	4,026–4,339	313	0 (66)	(66) 0
2.2. Ocean (Sao Tome Island – coast of South America)	4,339–10,560	6,221	0	0

Continuation of Table

1	2	3	4	5
3. South America		**3,417**		
3.1. Brazil		**2,304**		
3.1.1. Atlantic coast – Amazon Delta – Masara	10,560–10,751	191	0	5
3.1.2. Masara	10,751–10,755	4	5	7
3.1.3. Masara – Santana	10,755–10,763	8	7	18
3.1.4. Santana	10,763–10,766	3	18	3
3.1.5. Santana – jungle – border with Colombia	10,766–12,864	2,098	3	170
3.2. Colombia		**616**		
3.2.1. Border with Brazil – jungle – border with Ecuador	12,864–13,480	616	170	199
3.3. Ecuador		**497**		
3.3.1. Border with Colombia – Marian Jungle	13,480–13,554	74	199	248
3.3.2. Marian	13,554–13,562	8	248	250
3.3.3. Marian – jungle – mountain	13,562–13,738	176	250	3,246
3.3.4. Mountain	13,738–13,748	10	3,246	4,666
3.3.5. Mountain – Kuniburo	13,748–13,765	17	4,666	2,954
3.3.6. Kuniburo – Hacienda Tanda	13,765–13,784	19	2,954	2,480
3.3.7. Hacienda Tanda – San Antonio	13,784–13,797	13	2,480	2,406
3.3.8. San Antonio	13,797–13,804	7	2,406	2,773
3.3.9. Kalakali	13,804–13,813	9	2,773	2,730
3.3.10. Kalakali – jungle – Pacific coast	13,813–13,977	164	2,730	0
4. Pacific Ocean, Indonesia, and Wolf Volcano (ocean/land)		**18,746/1,501**		
4.1. Ocean (coast of Ecuador – Wolf Volcano)	13,977–15,224	1,247	0	0
4.2. Wolf Volcano (Galapagos Islands)	15,224–15,256	32	0–1,186	1,186–0
4.3. Ocean (Wolf Volcano – Marshall Islands)	15,256–25,809	10,553	0	0
4.4. Ocean (Marshall Islands – Indonesia)	25,809–30,644	4,835	0	0
4.5. Untitled island	30,644–30,644	0.05	11	2
4.6. Ocean (lagoon)	30,644–30,644	0.07	0	0
4.7. Untitled island	30,644–30,644	0.07	0–262	262–0
4.8. Ocean (lagoon)	30,644–30,644	0.26	0	0
4.9. Untitled island	30,644–30,645	0.1	0–77	77–0
4.10. Ocean (lagoon)	30,645–30,645	0.08	0	0
4.11. Untitled island	30,645–30,645	0.07	0–62	62–0
4.12. Ocean	30,645–30,646	0.81	0	0

End of Table

1	2	3	4	5
4.13. Untitled island	30,646–30,646	0.02	0–50	50–0
4.14. Ocean	30,646–30,646	0.03	0	0
4.15. Untitled island	30,646–30,646	0.08	0–20	20–0
4.16. Ocean	30,646–30,650	4.24	0	0
4.17. Untitled island	30,650–30,650	0.15	0–40	40–0
4.18. Ocean	30,650–30,651	0.64	0	0
4.19. Balabalak Island	30,651–30,654	3.26	0–254	254–0
4.20. Ocean (Balabalak Island – Dzhu Island)	30,654–30,709	54.73	0	0
4.21. Ocean (Dzhu Island – Gebe Island)	30,709–30,733	24.22	0	0
4.22. Gebe Island	30,733–30,735	2.49	0–72	72–0
4.23. Ocean	30,735–30,899	163.21	0	0
4.24. North Maluku	30,899–30,920	21.4	0–222	222–0
4.25. Ocean	30,920–30,967	47.3	0	0
4.26. Kayoa Island	30,967–30,970	3.11	0–320	320–0
4.27. Ocean (lagoon)	30,970–30,971	0.75	0	0
4.28. Untitled island	30,971–30,972	1.34	0	0
4.29. Ocean (Halmaher Sea, Molux Sea, Gulf of Tomini)	30,972–31,787	814.55	0	0
4.30. Sulawesi Island	31,787–31,811	24.24	0–378	378–0
4.31. Ocean (lagoon)	31,811–31,832	20.49	0	0
4.32. Sulawesi Island	31,832–31,835	3.21	0–320	320–0
4.33. Ocean	31,835–32,076	240.77	0	0
4.34. Kalimantan Island (farms and plantations, Pontianak)	32,076–33,005	928.92	0–831	831–0
4.35. Ocean	33,005–33,514	508.92	0	0
4.36. Lingga Island	33,514–33,524	10.85	0–10	10–0
4.37. Ocean	33,524–33,600	76.02	0	0
4.38. Sumatra Island (farms, plantations, settlements)	33,600–34,059	458.4	0–1,055	1,055–0
4.39. Ocean	34,059–34,201	142.38	0	0
4.40. Tanahmasa Island	34,201–34,210	8.73	0–25	25–0
4.41. Ocean (lagoon)	34,210–34,220	9.64	0	0
4.42. Untitled island	34,220–34,220	0.55	0–18	18–0
4.43. Ocean (strait)	34,220–34,222	1.72	0	0
4.44. Untitled island	34,222–34,223	1.53	0–15	15–0
5. Indian Ocean		**6,159**		
5.1. Indian Ocean (coast of Tanahmasa Island – coast of Somalia)	34,223–40,382	6158.7	0	0

Equatorial Linear City in the uWay Area

This article discusses the features of the ELC construction on land sections of the equatorial zone. The Table shows the land length on the continents and islands along the equator passing through territories of:

- Africa – 4,026 km (including 1,498 km of jungle);
- South America – 3,417 km (including 2,098 km of jungle);
- islands of Indonesia and Wolf Volcano – 1,501 km.

The distance length by land (including islands) is 8,944 km (including 3,596 km of jungle). The length across the oceans is 31,438 km. It should be noted that the distance by land is indicated according to the relief. If you count by the radius of the Earth, the length of land projected on the equator circle is 8,637 km. Speaking about the construction of the ELC in the uWay area, it is necessary to understand that we are not talking about continuous development. The structure of the ELC settlements is formed by a system of urban development complexes, united by a transport and communication axis. Design decisions for each complex are made taking local conditions into account.

The uWay with the functional elements of the system (clusters) located along it, is the main axis of the ELC. In order to determine the specific position of clusters on a particular territory, it is necessary to develop a feasibility study for the ELC construction. It will require detailed research and calculations for all elements of the complex.

The high level of the GPV automation and robotization does not exclude human participation. Maintenance and production personnel are present throughout the entire distance of the geocosmic structure. The construction of the ELC solves the life support task for all categories of workers employed in servicing the GPV, as well as for their families.

The main elements of the ELC are distributed along the uWay according to the general functional diagram. Their territorial position depends on the conditions of the area and in each case is determined with appropriate justification. The use of the uST elevated transport and infrastructure complexes greatly simplify the solution of transport accessibility problems [6, 8].

The main elements of the projected structure:

- the uWay with engineering and communication networks located on it;
- complexes of astronavigation and automated control of the GPV;
- energy clusters that provide energy to all parts of the geocosmic complex and the GPV takeoff and landing processes;
- production clusters for assembly, maintenance, and repair of the GPV units;
- sections of the global uNet network, as well as network of regional and intracity transport communications;
- logistics centers, transfer stations, passenger stations;
- residential complexes;
- clusters with educational, cultural, health, and sports institutions;
- clusters for the production and processing of agricultural products;
- conserved and developed natural complexes.

To substantiate the decisions made in the ELC design, it is necessary to refer to the technical normative legal acts (TNLA) operating on the territories of the equatorial belt states. Since the requirements of the TNLA may vary in different countries, it is necessary to develop and approve significant packages of documents with an international status when planning any of the ELC elements.

Generally, the current TNLA [15] stipulate to carry out planning and development of settlements and territories within the boundaries of their prospective development on the basis of state and regional programs of socio-economic growth, town planning regulations, and town planning projects of general, detailed, and special planning, approved in the prescribed manner. When developing clusters and linear objects of the ELC, the requirements of national legislation and those imposed directly on the elements of the structure being erected will be harmonized.

The planning arrangement of the ELC residential clusters is formed on the basis of a complex development, which includes:

- residential development with relevant social infrastructure facilities;
- pedestrian streets and community centers;
- elements of the natural and ecological framework (parks, squares, boulevards, and other common areas).

When planning and building residential clusters, special attention is paid to the safety of habitat for the human, plant and animal world. A thorough study of the area ecological picture precedes any construction. The environmental assessment procedure is a mandatory part of the feasibility study. If interference with the environment does not improve or maintain its condition, then such an intercession is unacceptable. Otherwise, the purpose of protecting and preserving the planet's ecosystem is lost.

New construction is often planned in established and habitable areas. A need may occur to carry out measures for their renovation. Territories that do not meet modern requirements and outdated transport and engineering communications are being modernized. At the same time, we use well-established methods of preserving naturally existing cities, freeing them from all excesses and consolidating all valuable and significant. Territories for new construction are located within the reach of transfer hubs and stations of the uNet network.

The ELC residential development is formed from self-sufficient harmoniously designed units. The main characteristic of each residential unit is the high quality of the living environment. Air, water, soil, as well as flora and fauna, are not oppressed or destructive. New settlers leave plenty of room for wildlife.

Residential Cluster as the ELC Element

The novelty of the idea inherent in the planning element lies in a residential building that is ecologically compatible with nature and creates conditions that maximally support its natural state. The building has built-in technologies that guarantee the full life cycle of the system and exclude any pollution of the environment. Several houses make up a group located within walking distance from the main functional areas of the settlement. Groups of buildings are combined into residential clusters containing complexes of social services and energy supply. This sector is not only a residential but also an economic unit of the ELC. Its area ranges from 1–2 km^2 (100–200 ha) with 1,000–1,500 m length and 1,000–1,500 m width (Figure 7).

The cluster is planned as an urban-type settlement, embedded in the environment. It comfortably houses from 2,000 to 5,000 people, providing them with everything they need, including food, water, energy, and access to a full range of modern services. Such integrity would enable the settlement to function self-sufficiently even during pandemic, temporary isolation or natural disaster.

The residential area of the cluster is divided into quarters, separated by a 100–200 m wide forest-park strip, where there are common areas for residents and guests: leisure and sports areas, various public buildings and structures, sports grounds, a stadium, a health center, a medical center, as well as shops, cafes, workshops, kindergartens, school. Forest-park strips (Figure 8) allow to arrange longitudinal and transverse uST routes for communication with parallel located linear settlements and their clusters. In the public area of the cluster, there may be offices or branches of various specialized companies involved in the GPV servicing.

Residential apartment buildings are interlocked into a single functional complex – a multi-apartment "horizontal skyscraper" with a length of about 400–500 m (Figure 9). One similar "skyscraper" connects 15–25 single-family houses 12–40 m long and 12–15 m wide each. The building has driveways at least 4 m wide for access to the land plot in the courtyard. House-apartment with a total area of 200–300 m^2 is designed to accommodate an average family of 3–5 people. Structures along the frontal length can be different – from 12 m (for 1–2 people) to 40 m or more (for a family of 10 people or more). The two houses are connected wall-to-wall on the ground floor. Driveways to personal plots are arranged between pairs of houses. The residential part of the buildings is designed according to the open planning principle. The structural scheme of the building provides the ability to organize the interior space at the request of its inhabitants.

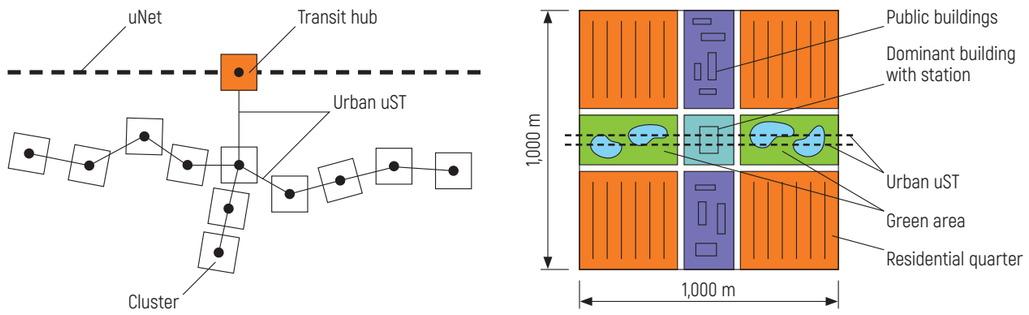


Figure 7 – Scheme of the residential cluster arrangement (variant)

Figure 8 – View at the residential cluster recreational area (variant)

Figure 9 – General view of residential development in the cluster (variant)

The roofs of houses are made in the form of glazed greenhouses, which are interconnected by a 2–3 m wide central communication corridor, intended for laying engineering networks and servicing suspended string transport. Technical rooms are arranged along the ends of the "horizontal skyscraper", cargo elevators are installed. The basement floor is built on a common foundation for the entire length of the "skyscraper" and has a 2–3 m wide technical passage (driveway) in the center intended for service equipment. There are premises for growing microgreens and mushrooms, keeping quails and other small birds and animals, as well as for breeding aquaculture. A condominium is organized for the joint operation of the building and management of technological processes at all levels. Any issues related to common property are discussed at owners' meetings.

Biotechnologies developed under the guidance of engineer A. Unitsky, provide for waste-free processes of growing and consuming food. At the end of the technological cycle, biological humus is produced instead of waste and can be returned as fertilizers to a new cycle. The cluster is provided with its own generating capacities included in the unified power system.

This principle naturally adapts the building to any geographic conditions and terrain features. It also applies to the mountainous part of equatorial zone. Rows of semi-detached houses are placed on organized terraces and take shape according to the relief. Rich landscape in the Andes region (South America) and picturesque landscape in the area of the Lake Victoria (Africa) allows new residential settlements to combine the achievements of modern civilization

and national architectural traditions. "Second level" transport complexes remove the restrictions inherent in mountainous surfaces – the relief difference does not prevent access to facilities. Engineering corridors are straightened and significantly reduce the length of the main communications. Previously inaccessible areas are becoming attractive and convenient for life.

The new system creates unlimited possibilities for a smooth change of residence. The population is becoming extremely mobile throughout the planet and even beyond.

Stages of the ELC Life Cycle

A new settlement element, like any capital object, passes through certain stages of its life cycle while functioning:

- plan – selection of effective use of the site;
- design – project development, obtaining expert opinions and approvals;
- construction – implementation of the project by the relevant contractors, fixing the erected object in the inventory and cadastral documents;
- treatment – emergence of property rights and encumbrances, conduct of transactions with real property objects;
- operation – maintenance and rational use of the objects' consumer potential;
- modernization – re-profiling or changing the functional purpose of objects with the elimination of removable physical wear and tear;
- disposal – demolition, dumping or reuse of materials, end of the object's life cycle [16].

Any capital object has its own service life. Some buildings become cultural, historical, and architectural monuments, but most of them turn into construction waste and create a problem for wildlife. The materials for their construction were removed from the natural environment, collected in a certain order, and prevented from returning to their initial place. However, they still remain in nature and take part in metabolic processes.

The new construction approach adopted during the arrangement of the ELC is based on the absolute elimination of negative influence on the environment. All processes in it are formed in order to eliminate:

- excessive consumption of energy resources;
- changes in the environment and landscapes;
- elimination of flora and fauna representatives or their displacement from the usual places of residence;
- transport system overloading and pollution of the atmosphere with construction equipment and dust (especially fine particles);
- negative impact on nature by wastewater;
- increase in the volume of household and industrial waste;
- pollution of water bodies;
- noise pollution;
- shading of territories and lack of sunlight;
- locations that are less resistant to earthquakes;
- jobs harmful to human health;
- fire risk.

The cluster arrangement of the ELC allows to maximize the ecological approach to construction work. The functioning of facilities and their maintenance are a priori harmless to the ecosystem. Limiting and regulating the size of residential clusters, new technologies for construction and operation ensure self-sufficient and non-waste processes in the life cycles, at the end of which all materials and structures are recycled or reused. The buildings and structures of the cluster are designed modularly, which makes it possible to easily replace defective elements and thereby extend the life of the system indefinitely.

Conclusion

The structure of the ELC, located along the uWay, is organized with regard to climatic and geological conditions, as well as the existing settlement structure. The dislocation of new settlement elements takes into account the conditions for the functioning of the GPV and allows the structure of the ELC to evolve in the process of its development. Settlements of the linear type are aggregated with "second level" transport systems into a single macrostructure. Further improvement of transport communications based on uST provides technical potential for the construction of a new type systems – linear cities. The ELC will become a link between the GPV and the global settlement system.

The implementation of the project begins with the development of a feasibility study for the construction of the ELC complex with the allocation of several stages, each of which is the basis for further detailing the concept.

At the first stage, the placement, layout, and technical details of the main elements of the ELC will be justified. In the future, it is planned to determine all aspects of the construction of the complex, including political and legal issues.

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UDC 341.1/8

Terms of Treaty Between Participating Countries of the uSpace Program

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The article provides a general description of the terms of international treaty; assumptions are made about the possible party composition of the treaty between the countries participating in the uSpace program realization; their role, rights, duties, and responsibilities in the process of implementing a large-scale international project – non-rocket space exploration using the General Planetary Vehicle (GPV) by A. Unitsky – are shown.

Keywords:
international treaty, international law, international cooperation, uSpace, General Planetary Vehicle (GPV).

Introduction

The universal scale of the uSpace program, which represents non-rocket space exploration with the help of the General Planetary Vehicle (GPV) as the only possible way to preserve the biosphere by transferring industry beyond the limits of the planet Earth [1], involves the interaction of a large number of independent parties. In order to achieve a positive result, it is important that the rights, duties, and responsibilities of the participants are clearly defined and legally secured. The most appropriate way in this case is the execution of international treaties.

The analysis performed by the author earlier [2] leads to the following conclusion: currently, there are no international documents that would allow participants to interact efficiently within the framework of the uSpace program. This is due to the fact that such documents regulate either overly general issues related to activities in space as a whole (for example, the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies), or, conversely, affect only the problems of a specific application area or project (for example, the Principles Governing the Use by States of Artificial Earth Satellites for International Direct Television Broadcasting).

The conclusion of a new international treaty regulating the process of implementing the uSpace program will contribute to efficient interaction between the participating countries by delineating their roles, defining and legally securing of rights, liabilities, and responsibilities.

The Agreement Among the Government of Canada, Governments of Member States of the European Space Agency, the Government of Japan, the Government of the Russian Federation, and the Government of the United States of America Concerning Cooperation on the Civil International Space Station (hereinafter referred to as the ISS Agreement), concluded in 1998, as well as documents developed within the framework of this agreement, is the closest in essence to an international treaty concerning the uSpace program implementation. At the moment, the International Space Station (ISS) is a unique object in the technical and legal senses. At the same time, this is an unprecedented international project in terms of the cost of creation, the number of stakeholders, and the scale of space activities. The ISS consists of elements designed and launched by the participants, but is considered a common object. The station is managed by the respective centers of the participating countries [3].

For the treaty on the uSpace program implementation being worked out, the availability of such a document is useful due to the acquired experience of interaction, as well as the fact that the successful functioning of the ISS proves the viability of such a type of cooperation as an international treaty on designing, construction, and operation of a uniform international facility consisting of elements belonging to various entities. However, it is necessary to take into account the specifics of the GPV – a super-scale (exceeding the size of the planet), super-complex (including dozens of cosmic, geocosmic, and terrestrial systems), and super-expensive (about 2.5 tln USD) complex passing through the territory of 11 countries and the maritime zone of several more states.

This article defines the concept of an international treaty, highlights its essential features for the uSpace program, gives a general description of the considered type of interaction of several independent subjects of international law, makes assumptions about the possible party composition, as well as the type, structure, and content of an international agreement necessary for the uSpace program implementation. In addition, it is important to note that this paper analyzes a universal international treaty without taking into account the specifics of a particular area of cooperation. This approach is preconditioned by the following factors: there are quite a lot of areas in which participants can interact, and each of them contains its own specifics. In this regard, the author focused on general norms, regardless of a specific subject.

Concept of an International Treaty

Before delving into the study of such a phenomenon as an international treaty, it is necessary to find out what is meant by this word combination. There are many definitions of this concept; the author has reviewed some of them.

1. The Vienna Convention on the Law of Treaties, adopted in 1969, refers to an international treaty as an agreement concluded between states in writing and governed by international law, regardless of whether such an agreement is contained in one, two, or more related documents, as well as regardless of its specific name [4].

2. According to many researchers, an international treaty is an explicit legal act concluded between two or more subjects of law, which defines the relationship between the participants by specifying their rights and liabilities in various spheres [5].

3. The Belarusian legislation proceeds from the fact that an international treaty of the Republic of Belarus is an international treaty (interstate, intergovernmental, or international treaty of an interdepartmental nature) concluded in writing by the Republic of Belarus with a foreign state (foreign states), an international organization (international organizations), another entity (other entities) having the right to conclude international treaties, which is governed by international law regardless of whether it is contained in one or in several related documents, as well as regardless of its particular name and method of conclusion (treaty, agreement, convention, solution, pact, protocol, exchange of notes or letters, and other names and methods of concluding an international treaty) [6].

Accordingly, each of the definitions focuses on the signs of specific objectives of such a phenomenon as an international treaty, therefore it will be reasonable to identify the essential features for the treaty on the uSpace program implementation. The author points out the following aspects among them:

- it is a document (one or several interrelated);
- it is concluded between subjects of international law (states, international organizations, etc.);
- it is expressed in writing;
- it regulates the relationships between the participants.

The following definition seems to be the most appropriate for the purposes of this article: an international treaty on the uSpace program implementation is an agreement concluded in writing between states and/or other subjects of international law regulating their interrelationships during the uSpace program implementation.

International Treaty Party Composition on the uSpace Program Implementation

According to the author, at the initial stage of the uSpace program implementation, it is more expedient to choose such a type of cooperation as an international treaty, concluding it at least between the countries on whose territories the GPV launch overpass (uWay) will be located. Taking into account the equatorial location, these will be the states, the list of which is given in Table 1. Additionally, this Table contains information on indicators characterizing the level of economic and political development of the prospective parties to the treaty.

In addition, during the construction of the GPV, it is necessary to take into account the fact that the uWay will run through the exclusive economic zone of the United States (a 200-mile zone around Baker Island in the Pacific Ocean) [9].

Taking into account the instability or underdevelopment of political systems, as well as the low level of economic and technical development of some of the listed countries (Table 1), it should be noted that in order to achieve a positive result, it will require an expansion of the scope of participants and the inclusion of highly developed states and/or international organizations capable of providing financing for a planetary-wide project and acting as a guarantor of the execution of the concluded agreement

Table 1 – Likely participating countries of the uSpace program implementation treaty and their individual development indicators

Country	Official language	Gross domestic product (as per purchasing capacity parity) per capita [7], USD	Fragile States Index* [8]
United States of America	English	63,415.985	38.3
Democratic Republic of Sao Tome and Principe	Portuguese	3,829.284	70.3
Gabonese Republic	French	15,970.052	69.1
Republic of the Congo	French	4,187.539	92.1
Democratic Republic of the Congo	French	1,106.371	109.4
Republic of Uganda	English	2,573.998	92.8
Republic of Kenya	English	4,925.519	90.3
Federal Republic of Somalia	Arabian	924.532	110.9
Republic of Maldives	Maldivian	19,608.983	66.2
Republic of Indonesia	Indonesian	12,221.919	67.8
Republic of Kiribati	English	2,199.787	–
Republic of Ecuador	Spanish	11,008.713	69.4
Republic of Colombia	Spanish	14,323.895	76.6
Federative Republic of Brazil	Portuguese	14,916.285	73

* The Fragile States Index of the countries of the world is a complex indicator that characterizes the ability (and inability) of the authorities of a state to control the integrity of its territory, the political, economic, social, and demographic situation in the country, as well as the stability of its state institutions [8]. The higher the value of the indicator is, the worse is the country's ability to control its internal affairs. For comparison: the Fragile State Index of Finland is 14.6 (the minimum indicator), Germany – 23.2, Belarus – 65.8, Russia – 72.6, Yemen – 112.4 (the maximum indicator).

(for example, a participant or participants in the ISS Agreement). At the same time, it should be mentioned that the above negative aspects can benefit the uSpace program: they will allow the parties to be interested in the advantage in the form of a rapid leap in their economic and technical development, which will occur due to the GPV construction.

Form and Structure of an International Treaty

All definitions quoted in this article arise from the fact that an international treaty is a document drawn up in writing. However, in theory, an international treaty can also be concluded orally, but in practice this is an extremely rare phenomenon. In any case, the implementation of a civilizational-scale project is impossible on the basis of oral agreements, so let us focus on the fact that a prerequisite for the existence of an international treaty on the uSpace program implementation will be its embodiment in a written form.

Neither international nor national legal norms have any strict rules regulating the structure of an international treaty (i.e., its constituent parts); taking into account the established practice, the following elements are most often distinguished:

- preamble;
- main part;
- final provisions;
- annexes (if available) [10].

The preamble, despite the fact that it does not contain any rules or norms, is an important part of the document, since it specifies the parties to the agreement, the goals for which an international treaty is concluded, and also prescribes the basic principles of the international law on which the created document is based.

In addition to the above, in the preamble of the international treaty on the implementation of the uSpace program, attention should be focused on what global challenges and problems humanity faces and how they will be solved within the framework of the project under consideration.

Since the construction of the GPV is a technically complex and innovative project [1], the author sees it important to supplement the text of the international treaty on the implementation of the uSpace program with a structural block containing terms and their explanations. The availability of such a section will lead to a uniform interpretation of the text, there will be no need to look for a definition of a concept in other documents and prove its meaning; it will exclude discrepancies and possible terminological conflicts of participants, which ultimately will result in simplification of interaction.

The main part of the treaty specifies its subject (what the document is aimed at), the rights and liabilities of the participants, describes the actions of the parties necessary to achieve their goals, tools and conditions for the fulfillment of liabilities, as well as responsibility for their non-fulfillment and permissible measures of legal coercion.

Considering the innovativeness and scale of the uSpace program, it should be noted that at the initial stage of its implementation it is impossible to clearly regulate the actions of the parties taken to achieve their goals, as well as to establish tools and conditions for fulfilling commitments.

For this reason, it is proposed to include in the main part reference rules indicating that detailed provisions will be described in annexes to the treaty. At the same time, it is important to provide for the procedure on attributing legal power to such annexes: the initiation of signing an annex, the deadline for its consideration by the participants, the voting procedure, a quorum, a sufficient number of votes, and a repeat procedure if necessary.

The section on dispute resolution deserves special attention in the text of the international treaty on the uSpace program implementation, since a large number of different entities and the complexity of relationships will obviously generate a significant number of mutual claims from participants. It seems appropriate to clearly regulate conflict resolution mechanisms, order of actions, applicable procedures, and competent authorities, which will simplify the resolution of disagreements.

The final provisions of an international treaty consist of norms that define the procedures required for its entry into force, including the need for ratification, the rules for making amendments and supplements to the text, the validity period, the procedure for early termination, conditions and actions for extension, the possibility of other entities to join the treaty, language, place of signature, list of annexes.

In addition to these rules, it is advisable to introduce a paragraph into the considered structural block of the international treaty on the uSpace program implementation, which establishes the procedure and methods of operational communication that include electronic communication channels (to simplify interaction between participants).

The Language of the International Treaty

The greatest difficulty in creating the final part is the issue of choosing the language in which the text of the treaty will be written.

An international treaty is most often drawn up in one language, provided that it is the official (one of the official) language of all participants. Two languages are usually used in bilateral treaties. In a multilateral agreement, when a large number of entities are involved, it is impractical to use all the official languages of the parties. In this case, the participants choose several of the most common languages for the text of the treaty [10]. At the same time, article 33 of the Vienna Convention on the Law of Treaties reads: if the authenticity of the text of a treaty has been identified in two or more languages, its text in each language has the same force, unless the treaty provides or the parties have agreed that in the event of a discrepancy between these texts, any one specific text will prevail [4].

The above-mentioned 14 likely participants in the treaty on the uSpace program implementation communicate in at least seven languages (Table 1).

According to the information posted on the official website of the UN, currently six languages (English, Arabic, Spanish, Chinese, Russian, and French) have official status in this organization [11].

The author believes that English, French, and Spanish should be chosen as authentic languages for the treaty on the uSpace program implementation, since they are the most common among the participants and at the same time are the official languages of the UN, as well as Portuguese as the official language of the largest entity (Brazil).

All the above provisions and specifics of the uSpace program implementation treaty being developed are schematically presented in Table 2.

Conclusions and Future Work

The study of the general provisions on an international treaty as a form of interaction of several independent subjects of international law conducted in this article allows to make the following assumptions about the possible composition of participants, the form, structure, and content of an international agreement necessary for the uSpace program implementation:

- the international treaty on the uSpace program implementation is an agreement concluded between states and/or other subjects of international law in writing, regulating their relationships in the process of implementing this program;
- the most prospective parties to the treaty (at least at the initial stage): the United States of America, the Democratic Republic of Sao Tome and Principe, the Gabonese Republic, the Republic of the Congo, the Democratic Republic of the Congo, the Republic of Uganda, the Republic of Kenya, the Federal Republic of Somalia, the Republic of Maldives, the Republic of Indonesia, the Republic of Kiribati, the Republic of Ecuador, the Republic of Colombia, the Federative Republic of Brazil;
- the author proposes a generally accepted structure of an international treaty, including such sections as the preamble, terms and definitions, the main part, dispute resolution, final provisions, annexes, and at the same time taking into account a number of important specifics and additional blocks.

Based on the logic of creating the document, the future study is planned to be focused on issues affecting the process of concluding the international treaty on the uSpace program implementation, its entry into force, and other formal procedures necessary to make the agreement legally in force, i.e., binding.

Table 2 – Structure and specifics of the international treaty on the uSpace program implementation

Sections (elements) of the treaty	Contents (features)
Preamble	The parties to the agreement; the goals for which an international treaty is concluded; the fundamental principles of international law on which the created act is based. Additionally: global challenges and problems facing mankind; their solution within the framework of the uSpace program
Terms and definitions	Uniform interpretation of the concepts and terms found in the text of the created treaty
Main part	The subject of the treaty; the rights and liabilities of the participants; the actions of the parties necessary to achieve their goals; tools and conditions to fulfill commitments; responsibility for their non-fulfillment; permissible measures of legal coercion. Additionally: reference rules indicating that detailed provisions will be provided in annexes to the treaty; the procedure for attributing legal force to such annexes: initiation of signing an annex, the deadline for its consideration by participants, voting procedure, quorum, sufficient number of votes, and a repeat procedure if necessary
Dispute resolution	Strict regulation of conflict resolution mechanisms; procedure for actions; applicable procedures and competent authorities to simplify the resolution of disagreements between participants
Final provisions	Procedures required for the entry into force of the treaty; the need for ratification; rules for making amendments and additions to the text; validity period; procedure for early termination; conditions and actions for extension; the possibility of other entities to join the treaty; language; place of signing; list of annexes. Additionally: the procedure and methods of operational communication, including electronic communication channels (to simplify interaction between participants)
Language of the treaty	The authentic text of the treaty should be presented in four languages: English, French, Spanish, and Portuguese
Annexes	Provisions detailing the main part of the treaty during the uSpace program implementation

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UDC 330.34

Scenario Substantiation of the Investment Project “Non-Rocket Near Space Industrialization”

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The EcoSpace program is based on the space vector of industrialization and the technology of non-rocket geocosmic transport. Saving the Earth’s biosphere from the anthropogenic impact of environmentally harmful and resource-intensive industries of the technosphere is carried out by transferring them outside the planet – into near space to near-Earth circular equatorial orbits. At the same time, man remains to live on Earth, which means that all vital industries on the planet (food production, power generation and transmission, housing and infrastructure construction, transport and communications) should be provided with eco-oriented technologies friendly to the biosphere. The EcoSpace program is an investment project, within which the authors in their articles consistently show various aspects of technical and economic feasibility of both the program itself and its constituent projects. This work considers a possible scenario plan for the preparation and practical implementation of the project "Non-Rocket Near Space Industrialization". An assessment of its feasibility and the EcoSpace program as a whole is presented.

Keywords:
asteroid mineral resources, non-rocket near space industrialization, biosphere, geocosmic transport, space vector of industrial development, space-industrial technologies, space solar power industry, General Planetary Vehicle (GPV), technosphere, technocratic way, civilizational development, eco-oriented technologies.

Introduction

The EcoSpace program, which is based on the space vector of industrialization and technology of non-rocket geocosmic transport, has the character of a global investment project "Non-Rocket Near Space Industrialization" (hereinafter referred to as the Project) [1]. It is designed to ensure the salvation of the Earth's biosphere by transferring all environmentally harmful and resource-intensive industries of the technosphere into space to the nearest near-Earth orbits located in the plane of the equator, i.e., beyond the limits of the biospheric home Earth.

The choice of circular orbits in the equator plane to accommodate the space industry is due to the desire to minimize the investment costs of its creation. Such a solution will also optimize operational expenses for the development of the space industry in the very costly geocosmic logistics along the Earth – Orbit – Earth route for billions of people who will continue to live on their home planet in the future.

At the same time, all the industry areas that are vital for man on Earth (organic farming and food production, generation and transmission of various types of energy, construction of housing and other structures, transport and communications, etc.) should be provided with new eco-oriented technologies.

The practical implementation of the EcoSpace program will mean global industrial re-equipment and the inevitable transition to the cosmoindustrial stage of development of our Earth's technocratic civilization. The fundamentals of the geopolitical and socio-economic structure will change radically, since all the basic branches of national economies (power industry, transport, mineral resources, processing of raw materials, and production of construction materials, etc.) will eventually transform into the basic branches of the global cosmoindustrial economy, common to all countries. Regulation of the geocosmic economy is planned from a single corporate center (with representation of all participating countries of this global Project).

The entire system of civilizational defense, designed not only to protect the planet from external space threats (including asteroids) but also to perform a peacemaking function on Earth itself, suppressing any military-political conflicts, should also report to the governing corporate center.

The world has not known and probably will not know a project that is more complex organizationally and technologically, longer in terms of preparation, implementation, and achievement of the final result, more global in scope and volume of investment costs, and most significantly, more important for the fate of all mankind, as well as urgent. At the same time, we note the following fact: the proposed idea is distinguished by an extremely high investment attractiveness.

To implement the EcoSpace program, like any investment project, a feasibility study is needed, and just for a single investor – the human civilization, represented by various, sometimes even diametrically opposed interests, which creates the main obstacle to the large-scale launch of the EcoSpace program, which engineer A. Unitsky announced about 40 years ago.

The authors of this article consistently reveal various aspects of the feasibility study of the EcoSpace program and its constituent projects. The most significant, complex, responsible, and at the same time the greatest of them, is the project "Non-Rocket Near Space Industrialization" [2]. This work discusses one of the possible scenario plans for the preparation and practical implementation of the Project, including the creation and launch of the General Planetary Vehicle (GPV), as well as the construction of the GPV takeoff and landing overpass (uWay) and the entire infrastructure on Earth in the equator strip and in space in near-Earth orbits, necessary to ensure geocosmic cargo and passenger transportation. In addition, the authors assess the sufficiency of technological, economic, and time resources of mankind within the framework of the proposed scenario plan.

Basic Scenario Plan of the Project "Non-Rocket Near Space Industrialization"

The basic scenario plan of the Project, designed for the next 40 years, is divided by the first launch of the GPV into two long-term stages lasting 20 years each. Engineer A. Unitsky [3] has previously proposed a breakdown into the following stages:

- the first stage (before the launch) – "Preparation for geocosmic flights";
- the second stage (after the launch) – "Practical industrialization of near space".

The stage of preparation for geocosmic flights was presented as a forecast schedule of capital expenditures for R&D, expenses for the construction of the uWay and its associated engineering infrastructure, as well as for the creation and construction of the GPV itself (Table 1).

The second stage, affecting the practical industrialization of near space, was presented as a forecast volume of geocosmic cargo and passenger flow, as well as an assessment of the main items of operating costs and revenues of electrical generation with an increasingly dominant return flow of space cargo to Earth in the course of increasing the capacity of the space industry (Table 2).

Table 1 – Costs schedule for R&D, creation, and construction of the GPV

Year	Expenses by years, bln USD			Total, bln USD
	R&D on the uWay "5-in-1", infrastructure, GPV, etc.	Creation of the uWay "5-in-1" and ground-based residential and industrial infrastructure (buildings, structures, power plants, power lines, communication lines, etc.)	Creation (construction) of the GPV	
1	0.1	–	–	0.1
2	0.2	–	–	0.2
3	0.3	–	–	0.3
4	0.4	–	–	0.4
5	1	–	–	1
6	2	1	–	3
7	3	2	–	5
8	4	3	–	7
9	5	4	2	11
10	6	10	3	19
11	7	50	5	62
12	8	80	15	103
13	9	150	50	209
14	10	150	75	235
15	10	150	100	260
16	10	150	100	260
17	10	150	100	260
18	10	150	100	260
19	10	150	100	260
20	10	150	100	260
Total	116	1,350	750	2,216

Table 2 – Cargo and passenger flow with cost and revenue estimates

Year (since the beginning of GPV operation)	Annual traffic volume, mln tons		Components of specific costs for geocosmic transportation per ton of cargo, USD/t				Specific cost of transportation, USD/t, (–) – profit
	Into orbit	To the Earth	Energy	Salary	Depreciation	Other	
1	100	10	525	90.9	20.7	63.4	700
2	200	50	450	40	20.7	39.3	550
3	300	100	300	25	20.7	24.3	370
4	400	150	200	18.2	20.7	21.1	260
5	500	200	150	14.3	20.7	15	200
6	500	250	100	13.3	20.7	11	145
7	400	300	50	14.3	20.7	10	95
8	300	350	–	15.4	20.7	8.9	45
9	200	400	–100	16.7	20.7	7.6	–55
10	100	500	–200	16.7	20.7	7.6	–155
11	100	500	–200	16.7	20.7	7.6	–155
12	100	500	–200	16.7	20.7	7.6	–155
13	100	500	–200	16.7	20.7	7.6	–155
14	100	500	–200	16.7	20.7	7.6	–155
15	100	500	–200	16.7	20.7	7.6	–155
16	100	500	–200	16.7	20.7	7.6	–155
17	100	500	–200	16.7	20.7	7.6	–155
18	100	500	–200	16.7	20.7	7.6	–155
19	100	500	–200	16.7	20.7	7.6	–155
20	100	500	–200	16.7	20.7	7.6	–155
Total	4,000	7,310					

Taking into account the realities associated with the indefinite long-term conviction of the world community and its elites, the authors supplemented the above two stages ("Preparation for geocosmic flights" and "Practical industrialization of near space") with another preliminary and currently experienced stage – "Formation of conditions for the start of large-scale implementation of the Project and the EcoSpace program".

The Project and the EcoSpace program have only one potential investor. This is a civilization that also needs to be formed and consolidated around the realization that the vector of space industrialization and the non-rocket geocosmic transport system have no alternatives not only in terms of saving the world from an eco-resource catastrophe but also in order to preserve the technocratic path of civilizational development, implying the use of limitless resources and the unique environment of space.

Today the human civilization is represented by a multitude of national interests (sometimes even hostile to each other), different levels of economic development, a large number of scientific schools, a number of business approaches, a variety of cultures and traditions. Consequently, the task of the newly specified stage, currently being implemented under the leadership of engineer A. Unitsky, is to substantiate and convince (and hence to consolidate) the world community and its scientific, business, and political elites that it is time to adjust civilizational development towards the space vector. And geocosmic transport can be only planetary and rocket-free.

As soon as such a conviction reaches a certain critical mass of the world consciousness, the process of organizational and legal consolidation will automatically begin. Most likely, this will happen under the auspices of the UN in the form of the creation of an international Consortium with the mandatory participation of the countries of the equatorial belt, as well as maximum possible number of countries with high economic, scientific, and technical potential [4].

Despite the fact that the developer of the Project and the EcoSpace program engineer A. Unitsky has already spent more than 40 years of his life on solving the problem of persuasion and consolidation of the world consciousness, nevertheless, the authors of this article are full of optimism and believe that within the next 3–5 years the Project and the EcoSpace program will be widely recognized in the world, and civilization will unite around the vector of non-rocket space industrialization.

This conviction is associated with an increase in scientific, media, and investment activity not only due to the efforts of the sole investor, the creator of the Project and EcoSpace program engineer A. Unitsky but also due to the objective growth of general concern about the steadily deteriorating environmental and resource situation on Earth as a whole. Indeed, there is an acute social demand for solving this problem, which is expressed in the constant expansion of the market of innovative space technologies and the number of its residents.

Stage "Preparation for Geocosmic Flights"

The main task of the preparatory stage of the scenario plan, designed for the next 20 years, is the creation of the GPV, the uWay, and the entire energy, transport, and logistics infrastructure.

However, as part of the preparatory stage and long before the construction of the GPV and the uWay, the Equatorial Linear City (ELC) should be founded. Using its enterprises, the GPV should be manufactured. On the territory of the ELC (i.e., along the equator), it is necessary to open transport and logistics hubs connected with multispeed string-rail routes built using Unitsky String Transport technology (uST). It is obvious that such a large-scale construction site on the equatorial strip will require reconfiguration of the global transport and logistics system so that it can begin to service meridional cargo and passenger flows around the perimeter of the equator, delivering materials and equipment to the ELC. After the completion of its construction, the need for servicing meridional cargo and passenger flows will not disappear, but their direction will change, since raw materials, goods, and products coming from space will be transported from the territory of the ELC all over the Earth.

It is planned to set up a completely different urban lifestyle in the ELC: new standards of housing, social and household infrastructure, eco-comfortable biosphere, food supply system will be created. The ELC will have its own agro-industrial sector. The city layout of the ELC (and this is the entire equatorial strip, including oceanic areas occupying about 80 % of the urban area) should acquire a general plan and a sectoral administrative-territorial division with a choice of locations for large, medium, and small administrative centers. Such an approach will greatly determine the future of the global transport and logistics system. In addition, an urban planning code, building codes and rules, and many other documents regulating construction should be developed and approved for the ELC. All these are uneasy tasks that also require large-scale R&D.

Taking into account the enormous length of equatorial linear objects, amounting to over 40,000 km, their construction should be carried out simultaneously on many sites along the entire equator. In particular, given the duration of any linear construction (three years) and the average passage rate (150–200 m/day), it will be necessary to arrange about 200 construction sites along the equator.

At the same time, by the end of the preparatory period and by the time of the first GPV launch, the structures and equipment for the orbital linear city should expect transportation into space at the warehouses of the ELC. They will include elements for the construction of its prestressed base, as well as everything necessary for the deployment of the first space solar electric and hydrogen stations, the launch of space tow rockets with special mining equipment (needed in the first exploration expeditions to asteroids), the installation of the first residential and industrial clusters in orbit, etc.

It is necessary to make up a sufficient fleet of cargo and passenger modules for the first launch of the GPV. Cargo modules will be used not only for delivery but also for short-term storage of cargo in space (while industrial clusters are being built). Passenger modules will be required both for the transportation of passengers into orbit and for the arrangement of temporary accommodation and places of work for cosmic personnel.

The preparatory stage should begin with the full-scale deployment of comprehensive R&D, affecting a wide range of issues. Development and project designing will be carried out not only during the entire preparatory period but also after it, and it is unlikely that they will ever stop, because the problems that will have to be solved within the framework of the space industrialization are as limitless as the outer space itself.

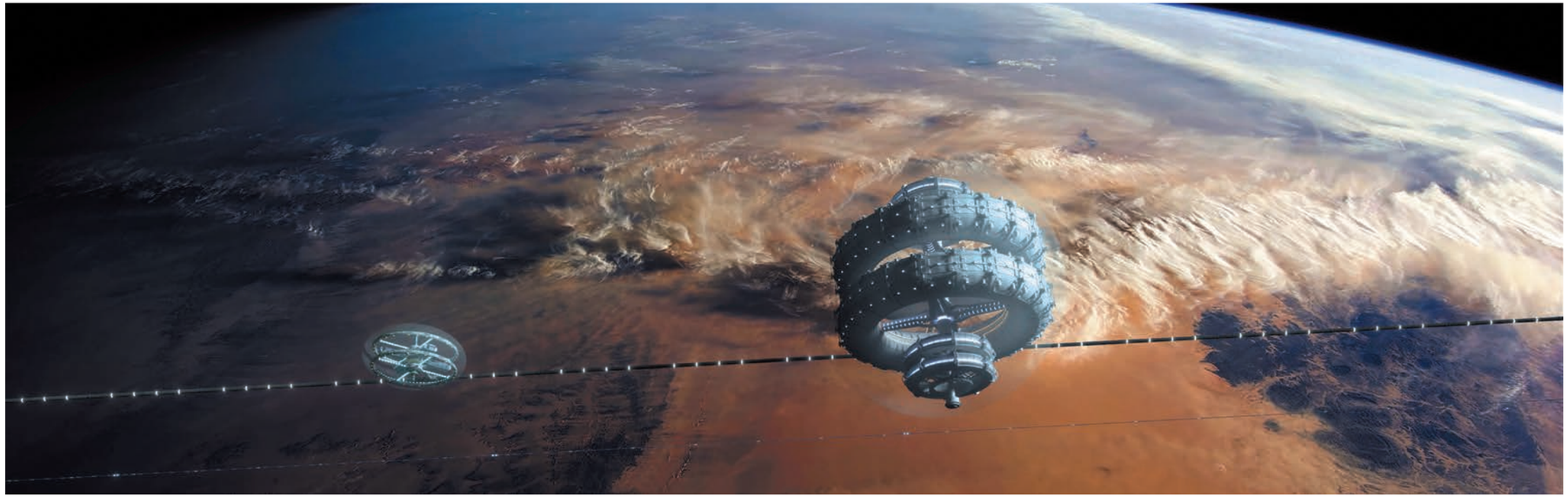
It should be particularly noted that the technological re-equipment will affect not only aspects related to the creation of the GPV, the uWay, and the required infrastructure. A person is part of the Earth's biosphere being saved and will remain living on the planet that gave birth to him. This means that he will not be able to do without eco-oriented technologies for food production, energy generation, construction of transport, housing, industrial, and residential infrastructure. Engineer A. Unitsky has been working in this direction for a long time. To date, he has achieved breakthrough results and is already implementing the entire line of eco-oriented technologies (being developed in a group of international companies set up by him): uGreen, uEnergy, EcoHouse, and uST.

As part of the GPV creation, the following list of main issues will necessarily be included in the R&D: design and layout scheme; thousand-kilometer linear electric motor and magnetic suspension; linear (belt) flywheels-rotors and vacuum channels for them; power supply, recovery, and extraction of thermal energy; management and safety; functional systems of cargo modules and life support systems for passenger modules as autonomous space satellites; space transportation of bulky cargo on the hull of the GPV.

In addition, a wide range of tasks must be solved: optimization of the structural materials and working environments used; creation and testing of small and large physical models; mathematical modeling of operating modes, including launch and landing ones, especially in the mountains; stabilization of super-long structure with uneven loading; calculations of operating modes for numerous possible emergency situations; operation and routine maintenance, including the inter-flight one; antiterrorist and antimeteorite protection of all structures and their vandal-proof design; arrangement of manufacturing the GPV components and modules, their delivery to the assembly site along the entire equator, installation and commissioning, quality control; search for energy sources; acceleration of belt flywheels with access to the desired hyper-speed modes, etc.

During the construction of the uWay and its accompanying infrastructure, the following main issues must be developed as part of R&D: vertical and course profiling of the launch overpass, especially in the highlands, as well as in oceanic areas characterized by great depths, strong currents, and unstable navigation; power generation, supply and accumulation of cargo and passengers along the entire equatorial overpass, which has a length of more than 40,000 km; laying of equatorial transcontinental string-rail tracks parallel to the uWay for express, high-speed, and hyper-speed cargo and passenger transportation; urban planning and construction of transport and logistics, energy, and industrial nodal components of the ELC, including residential, social, and household sectors containing agricultural land and food production. The floating nodal components of the linear city, which is located on oceanic sections occupying about 80 % of the length of the equator, will require special attention.

The preparatory stage should begin with the development of all possible standards, regulations, and rules, which will allow the newly created components of the geocosmic transport and infrastructure complex to be in harmony with each other. The preparatory stage will be completed with the first GPV launch. The next stage (practical industrialization of near space) will begin at the same time.



Stage "Practical Industrialization of Near Space"

Within the framework of the considered stage, designed for the next 20 years (after the first GPV launch), the authors have identified five main phases. As a result of the implementation of each of them, the newly created space industry passes over to a new qualitative and quantitative level.

The first phase of the near-space practical industrialization stage (duration – two years) will be held under the slogan "Creation of space power industry and the first space construction".

Planned work during this phase:

- lifting of the first equipment and the formation of a space construction and installation complex, including robotic manipulators, rockets with the function of towing and battery stations, habitable modules for the placement of control points for construction and installation equipment and space construction in general, cargo modules for the storage of construction materials, consumables and repair parts, as well as other stocks necessary during construction;
- deployment of the first units of the orbital grouping of space-based solar power plants (SBSPPs), including integrated stations for the production, liquefaction, and storage of hydrogen-oxygen fuel intended for space tow rockets, which are used for transporting robotic manipulators on space construction sites and moving cargo outside the Earth orbits and over long distances into deep space;
- lifting and installation of the first stage of linear components of the Industrial Space Necklace "Orbit" (ISN "Orbit"), including the orbital support frame, track structures of express rail and high-speed levitation transport, electric power and fiber-optic cable lines;
- fitting-out and sending the first deep space mining exploration expeditions to the Moon and the nearest asteroids in search of mineral raw materials;
- rendering of the first space services, primarily the launch of new Earth satellites and maintenance of the operating ones, as well as the collection of space garbage, restoration of the ozone layer, etc.;
- conducting the first geocosmic excursions.

The main task of the first phase is to provide space energy for the new space construction and, in fact, the arrangement of space construction, debugging of construction technologies, and increasing the pace of their implementation.

The second phase of the practical industrialization of near space (duration – three years) will be held under the slogan "Creating the basis for the industrialization of near space – the ISN "Orbit".

Planned work during this phase:

- completion of installation of all linear components of the ISN "Orbit" support frame, their power interlocking into a single structure, and additional acceleration to the orbital velocity, which guarantees the required level of internal stresses, which provide the frame with the needed supporting load-bearing capacity;
- assembly and commissioning of a stationary orbital transport service (intended for transportation of cargo and passengers along the ISN "Orbit"), as well as electric power and fiber-optic networks (supporting geocosmic communications of energy and information);

• start of construction in the first industrial clusters of objects of cosmic residential and industrial infrastructure (electric transformer substations, transportation and logistics hubs, data centers, stations of air and water generation, as well as disposal of carbon dioxide and waste water, etc.);

• increasing the capacity of space electric hydrogen power industry and the number of geological exploration industrial expeditions, access to the energy resource markets of the Earth;

• expanding the volume of space services provided at the geocosmic transportation market;

• increase in the flow of space tourists.

The main task of the second phase is the commissioning of the ISN "Orbit" as the basis of the newly emerging space industry.

The third phase of the stage under consideration (duration – five years) will be held under the slogan "Creation of space industry".

Planned work during this phase:

• deployment in built industrial clusters of new space production facilities of structural materials and machine-building equipment necessary for space industrial construction;

• resettlement of personnel arriving on space business trips, including those for a long time with their families, as well as the development of space hotel service and the distribution of the growing flow of space tourists in EcoCosmoHouses (ECHs) [3];

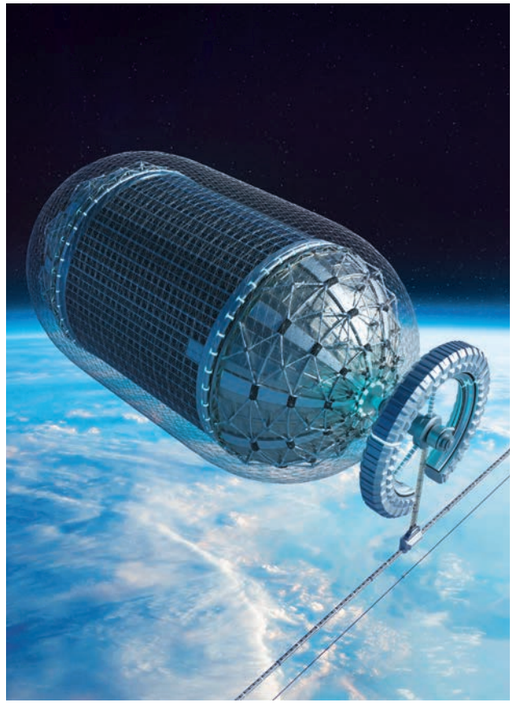
• creation of the space organic farming industry in orbital ECHs, storage and processing of the resulting crop, making of food products from it, development of pharmaceutical and other industries based on space raw materials of vegetable and animal origin;

• increasing the volume of space services provided and taking a dominant position in the geocosmic transportation market;

• strengthening the capacity of the space electric hydrogen power industry, as well as increasing the number of geological exploration industrial expeditions and occupying dominant positions in the energy and raw materials markets of the Earth;

• expansion of the number of orbital linear sections prepared technically for cluster development and the number of industrial clusters.

The main task of the third phase is the creation of a space industry that covers its own needs of space construction, entry to the Earth's markets of energy and raw materials, occupying



a dominant position in the market of geocosmic transportation and space services.

The fourth phase of the stage under consideration (duration – five years) will be held under the slogan "Self-sufficiency of space construction and dominance in the markets of energy and raw materials of the Earth".

Planned work during this phase:

• strengthening the capacity of space-based solar electric hydrogen power industry and occupying a dominant position in the Earth's energy market (by decomposing water into hydrogen and oxygen using solar energy and delivering hydrogen to the Earth);

• increasing the number of geological exploration space expeditions and gaining a dominant position in the raw materials markets of the Earth;

• expansion of the number of orbital linear sections prepared for cluster development and the number of industrial clusters;

• increasing the space production facilities of structural materials and machine-building equipment intended for space industrial construction;

• resettlement of personnel arriving on a space business trip, including those for a long time with their families, as well as the development of space hotel service and the distribution of a growing flow of space tourists in constructed ECHs connected to each other in an orbital linear city;

• development of space organic farming, increasing the yield and production of food from it, reaching full self-sufficiency of people in space with food, pharmaceutical, and other products of vegetable and animal origin grown in ECHs;

• expanding the volume of geocosmic transport and other space services provided – achieving absolute monopoly dominance (excluding flights of rockets with thermochemical jet engines);

• implementation of a set of measures aimed at preparing the space environment for the mass arrival of free market residents of the space industry, including the development of measures to stimulate economically the growth of space enterprises (preferential credit conditions, favorable rental rates for industrial and habitable areas, low tariffs for energy, transport logistics, and resources, etc.), development of social and household infrastructure for space personnel who arrived with their families, formation of administrative and law enforcement systems, etc.

The main task of the fourth phase is to occupy dominant positions in the energy and raw materials markets of the Earth, an absolute monopoly position in the market of geocosmic transport and space services, as well as creating conditions for the widespread space industrialization.

The fifth phase of the stage under consideration (duration – at least five years) will be held under the slogan "Broad space industrialization".

During this phase and for an infinitely long time to come, it is planned to provide newly arriving free market residents with their own space investment projects with everything they need – preferential loans, space electric energy and hydrogen fuel, space raw materials and materials at favorable rates; provision of geocosmic transport and space services on privileged terms; provision of rental and leasing of robotic labor, industrial and habitable spaces; etc.

The main task of the fifth phase of the practical industrialization of near space is to complete the process of a dynamic industrial restructuring of the Earth's technosphere to the space vector and the final removal from the agenda of questions about the risks of developing ecological, resource, demographic, social, and other catastrophic scenarios on the Earth that hinder the sustainable evolution of the Earth's technogenic human civilization infinitely in Time in the infinite Space of our Universe.

Assessment of the Realism of the Proposed Scenario

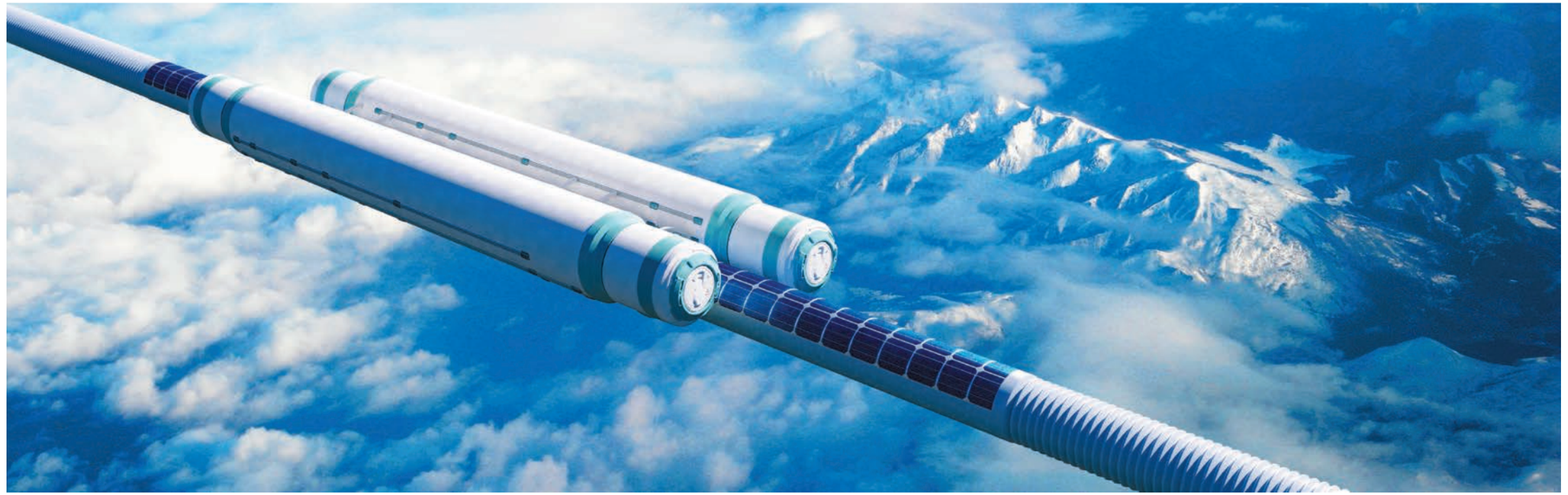
The realism assessment of the proposed scenario is an important part of the project "Non-Rocket Near Space Industrialization" substantiation and the EcoSpace program as a whole. For such an analysis, the authors of the article have studied the ascending cargo-passenger flow, compared it with the GPV carrying capacity and the frequency of flights.

The first and second phases of the industrialization of near space are associated with enormous volumes of construction and installation work. First of all, this is the construction of the ISN "Orbit" with a length of 42,520 km (at an altitude of 400 km). The installation of its linear structures should be carried out simultaneously along the entire perimeter of the orbit – at about 500 construction and assembly sites with a passage rate of about 100 m/day, which is quite achievable, taking into account the size of the linear segments of the structure (up to 100 m long). Each such construction and assembly site will be equipped with space tugs, teams of anthropomorphic construction robots, which are controlled from a short distance by groups of operators located in the inhabited modules, as well as a fleet of cargo gondolas for temporary storage of equipment, workshops and fuel, water, and food supplies in them. From the first days, it is necessary to carry out the installation of energy facilities (for example, at another 250 construction and assembly sites).

The total weight of construction equipment of one construction and assembly site is expertly estimated at the level of 500 tons. Accordingly, the total weight of all construction and assembly sites that need to be lifted into near-Earth orbit during the first flights is about 2 mln tons, which will be about 20 % of the carrying capacity of one GPV flight.

The total weight of the linear structures of the support frame of the ISN "Orbit", which will need to be raised and mounted in the Earth orbit during the first five years of the practical stage of the non-rocket near space industrialization, is estimated by experts at 200 mln tons. That is, 20 flights will be needed for their delivery (on average, four GPV flights with full loading per year).

The total weight of 1,000 SBSPPs (each with a capacity of 1 GW and a weight of approximately 100,000 tons [5]) that need to be lifted and mounted in the Earth orbit to provide 1 TW of net power in space (with a global net capacity



of 7.14 TW in 2018 [6]) will amount to 100 mln tons. To arrange such a space power system, 10 flights will be needed in the first five years (on average, two GPV flights with full loading per year).

The total weight of installations for the production of 50 mln tons of hydrogen per year, including its liquefaction and storage, which should be lifted and mounted in the Earth orbit during the first five years of the practical stage of the non-rocket near space industrialization, will be no more than 10 mln tons. That is, one flight will be needed to deliver this cargo (on average, one GPV flight with a 20-percent loading per year).

The total weight of structures and filling components of one industrial cluster with an area of 750,000 m^2, serviced by personnel of 5,000 people (with families), will be about 3 mln tons. One industrial cluster includes ECH in the shape of a torus (weighing 400,000 tons [3]), which makes it possible to create an eco-comfortable habitat in space with artificial gravity and terrestrial landscape. In addition, it is necessary to add a block weighing about 2 mln tons, which contains 100 uninhabited workshop premises, each with an area of 10,000 m^2 and 2,000 tons of equipment. About 100 such industrial clusters need to be raised and mounted in the Earth orbit during the first five years of the third phase of the practical stage of non-rocket near space industrialization. Their total weight will be about 200 mln tons. That is, 20 flights will be needed to deliver this cargo (on average, four GPV flights with a full loading per year).

In the first five years since the start of GPV flights, it is planned to equip about 100 industrial geological exploration expeditions to the Moon and asteroids. The average weight of equipment in each such expedition is estimated by experts at 100,000 tons. Thus, the total weight of the expedition equipment that needs to be lifted and sent to the space industrial expedition from the Earth orbit during the first five years of the practical stage of non-rocket space industrialization will be about 10 mln tons. That is, one flight will be needed for their delivery (on average, one GPV flight with a 20-percent loading every year for five years).

From the first days of space industrialization, it is planned to provide services for launching satellites into the equatorial orbits of the Earth, however, taking into account the increased availability of tariffs, the demand for such services is projected to be much greater. New services will be offered to the market – the collection of space garbage (its volume is estimated by NASA experts at the level of 8,000 tons [7]), as well as maintenance, refueling of satellites operating in orbits, and their replacement with satellites located in circular equatorial orbits, since satellites placed in other orbits will cross the plane of the equator during their movement, which means they will pose a threat to the GPV and the ISN "Orbit". The gross volume of cargo transportation in this segment is unlikely to exceed 1 mln tons per year in both directions, i.e., one GPV flight with a 10-percent loading will be required per year.

The newly opened direction of mass space tourism (for example, 100,000 travelers in the first year, followed by an annual doubling of their number) will require only a small fraction of the GPV loading – within 1 % (taking into account the average weight of one tourist and his luggage as 100 kg).

Conclusions and Future Work

The above detailed basic scenario of the project "Non-Rocket Near Space Industrialization" and the EcoSpace program allows to assert that the enlarged basic scenario previously proposed by engineer A. Unitsky [8] is fully feasible.

Even in the first tense years of practical near space industrialization stage, the number of GPV flights with full loading will not exceed 12 flights per year, or one flight per month (despite the fact that such a geocosmic transport system is capable of making one flight every week).

The issue referring the possibilities of the Earth's technosphere and biosphere to provide such a large-scale volume of construction with resources requires additional study. This task will be the subject of a feasibility study in the next research.

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UDC 65.011.8:629.7

Selection of Industries for Their Transfer to Near Space

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Based on a review of scientific literature and an analysis of specific gross indicators of human development during the past 30 years (related to the natural ecological and industrial components), we have concluded that it is necessary to transfer terrestrial industries to near space as the only possible scenario for saving the Earth's technocratic civilization from future destruction. Due to the criticality of determining an approach to selection of specific industries (manufacturing facilities, enterprises) for their transfer into space and absence of such methodological tools to date, an appropriate author's model has been proposed, with recommendations on its actual implementation.

Keywords:
biosphere, near space, environmental pollution, practicability index, space industrialization, criterion, assessment methodology, industry relocation, energy resources.

Introduction

The Earth's civilization, that chose a technocratic vector of its development tens of thousands of years ago [1], is moving towards technical and technological expansion with an ever-increasing acceleration. Every day, spectacular scientific developments are introduced; various life processes are automated and robotized; new increasingly tall skyscrapers of incredible shapes are built, etc. The mission of technological progress in a general sense is to increase labor productivity and to spare human working time [2], which is a real success. V. Baynev, a Belarusian scientist, stressed that technical and technological progress is nothing more than a process of improving equipment and technologies due to a substitution of human (physical, intellectual, creative) energy by natural forces [2].

However, progress in human development has had both positive and negative results. One of the main negative trends, that is becoming more acute with every passing year and is, therefore, discussed in some detail in this article, is a deteriorating environmental situation on the planet that can be described as follows: two or three generations remain to the point of no return for the Earth's technocratic civilization, thereafter its degradation and extinction cannot be stopped [1].

The technosphere created by one species of living organisms, *Homo sapiens*, has become, over the past two centuries of industrial development, a principal and, in fact, the only source of destructing the planet biosphere that has been formed by millions of species of living organisms over billions of years of evolution. The main structural elements of the living biosphere (oxygen and ozone layer of the atmosphere, fertile soil, coral islands, etc.) are formed from the waste metabolism of microorganisms, flora and fauna. The dead technosphere appeared inside the biosphere on the basis of entirely different, antagonistic principles; the result of its "metabolism" is a waste that is absolutely different: exhaust and flue gases containing hundreds of carcinogens, tire and asphalt wear products, acid rain, slag, sludge, ash, spoil banks, etc. The planetary expansion of the technosphere that has grown to the scale of the biosphere destroys the living shell of the Earth with these dangerous substances and threatens to reach the point of no return, and to become irreversible.

Thus, many scientists agree that a transfer of industrial capacities from the Earth to the orbit or to a more distant space is inevitable; it is one of the key directions in transition to a sustainable development of anthropogenic civilization [1, 3, 4] and saving the biosphere and humanity. The main arguments on this issue are as follows: exhaustion of limited raw materials and other natural resources, negative impact on ecology and climate, overpopulation of the planet. Many of the planet ecosystems are already on the verge of being destroyed by human over-exploitation. This is why the idea of industrial and commercial development of space resources becomes real to the extent that some American universities are planning to train space geologists and miners [4].

At the same time, despite the predicted (according to the authors, inevitable) industrialization of near space, in numerous scientific works and open specialized sources, there are practically no works dedicated to a fundamentally significant problem: how (based on what methodological apparatus) shall we select industries for their subsequent transfer to near space?

Accordingly, the purpose of the study is to substantiate the need to transfer terrestrial industries into near space and to develop a methodological apparatus for assessing a feasibility of such action in relation to various types of manufactures (industries).

The tasks that have been solved within this article are as follows:

- argumentation of the importance of the outer space industrialization, including on the basis of analyzing specific gross indicators of human development over the past 30 years and established negative trends;
- study of scientific publications and data in the open sources of information with an identification of lacking methodological approaches to a selection of manufactures (enterprises, industries) for their transfer (relocation) into space;
- creation of a methodology for assessment of practicability to transfer industries to near space and elaboration of recommendations on its actual implementation.

Literature Review

The analysis of specific indicators of human development related to the natural ecological and industrial components in the general planetary dimension for 1990–2018 is presented in Table 1.

The information presented in Table 1 indicates a deterioration (aggravation) of the environmental situation in the world, a constant increase in the load and the degree of human impact on the enclosure of the planet inhabited by living organisms – the biosphere. Thus, the number of people living on Earth has increased by almost 1.5 times over the past 30 years, while the increase of the share

Table 1 – Analysis of specific gross indicators of human development (in 1990–2018)*

Indicator name, unit of measurement	Values by years			Growth rate 2018 to 1990, %
	1990	2005	2018**	
Earth's population, bln persons	5.28	6.51	7.59	+43.75
Electric energy consumption, kW·h/person	2,127	2,656	3,412	+60.35
Energy consumption, tons of oil equivalent/person	1,663	1,767	1,922	+15.53
Arable land area, ha/person	0.23	0.21	0.18	–19.3
Forest area, % of land area	31.63	31	30.72	–2.88
CO_2 emissions, t/person	4.25	4.31	4.56	+7.29
Fuel export, % of total commodity export volume	10.71	13.37	14.25	+33.05
Electric energy production from oil, gas, and coal sources, % of global volume	61.94	65.76	65.24	+5.33
Added value in industry (including construction), tln USD (2010 costs)	11.86	16.21	23.15	+95.19
Industrial employment, % of global employment	21.86	21.13	22.93	+4.89

* Based on data in [5].
** Some indicators present data for 2016.

in total energy consumption and carbon dioxide emissions (per capita) has become still greater; the added value in industry has almost doubled (together with the ever-increasing volumes of industrial production). This has resulted in a significant reduction in the area of arable land and forests. In spite of numerous remedial (recreational) activities undertaken by governments and international organizations, it is impossible to stop this trend.

The data presented in Table 1 can be supplemented with the following actual facts:

- according to scientists at the University of Texas at Austin, USA, global air pollution reduces a person's life expectancy by an average of a year (mainly due to emissions of harmful substances by factories and various modes of transport) [6];
- according to estimates of the World Health Organization, poisoning of the atmosphere annually leads to the death of about 7 mln people [7] (0.1 % of the total population of the planet), of which about 800,000 cases are reported in Europe [8].

Russian scientist V. Klyushnikov emphasized in his work that a permissible limit of energy production on the planet Earth is about 0.1 % of the solar energy coming through the atmosphere to the Earth's surface, which corresponds to about 90 TW (90 bln kW). When this limit is exceeded, irreversible processes of habitat destruction begin in the Earth's environment. If the existing trends of industrial growth are maintained in 2100, the total energy production should increase to 98 bln kW, i.e., a permissible rate will be exceeded with all resulting consequences that are fatal for humanity [9].

Thus, the only justifiably feasible and appropriately figurative scenario for saving the planet from imminent catastrophic environmental problems in the near future is the industrialization (industrial development) of space.

The head of Amazon and Blue Origin J. Bezos claims that space was primarily interesting for its energy resources, as they would be sooner or later depleted on the Earth [10]. That is why the development of energy-intensive industries in space will allow, V. Klyushnikov adds, to improve radically the environment and turn the Earth into a flowering garden [9].

According to a former NASA staff member, Professor of the University of Central Florida (USA) F. Metzger, the Solar System can set up production facilities that are many times exceeding those available currently on our planet [10].

This assessment is also confirmed by a Belarusian scientist and inventor, the creator of a geocosmic transport system and a number of transport infrastructure projects based on string technologies, A. Unitsky: space presents ideal conditions for the most modern technologies. There, a natural environmentally friendly thermonuclear reactor

called the "Sun" has been operating all year round, day and night, for 5 bln years already that will provide the extraterrestrial industry with energy without any side effects, such as Chernobyl, for millions of years of technological development. There are unlimited raw materials, energy, technological (zero gravity and deep vacuum), and spatial resources [1].

Currently, there is already a sufficient number of industries where vacuum technologies are used that allow significant improvement in properties and quality of manufactured goods (products, services): nuclear, metallurgical, aviation, chemical, electronic, pulp and paper industry, and mechanical engineering [11]. For instance, if a steel manufacturing process were transferred to space, the alloy would not contain oxygen, nitrogen, and other elements. Accordingly, a degassing process will be provided a priori, which would prevent formation of all sorts of defects (non-metallic inclusions) that significantly impair the quality of a resulting product, and at the same time optimize the physico-mechanical and strength characteristics.

Generally, the concept of industrial space exploration originated at least a century and a half ago. It was also mentioned by the Russian religious thinker and philosopher-futurologist of the 19th century, N. Fedorov who is called the precursor of the cosmic ideas of the great K. Tsiolkovsky [9, 12]. One of the points of K. Tsiolkovsky's program, which provides for the phased exploration of outer space and at the same time is the first full-fledged theory in history about the industrialization of space (1926), was the section "Industry Develops in Space" [12, 13].

Thus, the conclusion is obvious currently: a massive and rapid development of space as an unlimited space for deployment of industrial technologies is extremely urgent from various points of view, as space industrialization is the only way to preserve and develop civilization [14].

This solution is supported by many scientists, companies, and states. Cosmic space with its possibilities and potential resources is of great interest for both governments of many countries (USA, Russia, China, India, etc.) and large private business (companies such as DST Global, USM Holdings, S7 Airlines, Virgin Group, Facebook, Google, Amazon, etc.) that invest considerable funds in this promising area [10, 15]. The mankind will be still more active in exploring cosmic space, it will continue until the time when industrial enterprises will be deployed (in the near future) outside our planet [10].

At the same time, scientific papers of a limited number of authors (Belarusian and foreign) present ideas and single conceptual approaches in relation to the scientific and practical issue of selecting specific industries for their deployment on the near-Earth orbit.

Such conceptual and practically oriented study and appropriate justification is primarily contained in numerous works by the founder of rocketless near space exploration, A. Unitsky. In particular, he notes that the Earth will only preserve as industries agriculture and medicine, science and education, green transport and infrastructure, ecologically friendly construction and pedestrian linear cities, as well as single, environmentally safe structural elements of global energy industry, communication, and mechanical engineering, service industries [14]. The Belarusian inventor contends also that the agrarian sector is transforming significantly; industrial manufacture, scientific laboratories, factories, workshops (primarily those in the energy, mechanical engineering, metallurgy, and chemical industries) will be gradually transferred to the Earth orbit (created anew) [1]. Besides, unique physical characteristic, such as zero gravity, deep vacuum, technological cleanliness (absence of dust and microorganisms), radiation, cryogenic and ultra-high temperatures present in space [1] suggest an important advantageous factor for transferring terrestrial industries into space. Engineer A. Unitsky resumes: objective reasons will cause a future transfer of the terrestrial material production into space nearly completely [1].

Expert A. Babayan remarks within the study carried out in 2019 that the cosmic vector of space industrialization should involve the transfer of the following industries (product lines) beyond the planet limits: geocosmic transport (represented by the General Planetary Vehicle (GPV)), space solar power industry, mineral resource extraction and processing. According to him, the above industries are the most troublesome in regards to environmental pollution and Earth resource exhaustion [16].

Russian specialist N. Sinyuk believes that it is required to remove a larger part of energy and material consuming industrial facilities from Earth, in order to save the planet for humanity. Here, an evident advantage on the global planetary scale may be a space transfer (on near-Earth and other orbits, planets and their satellites, asteroids) of primarily environmentally dangerous manufactures, followed by energy and material consuming ones, and subsequently all manufactures and their supporting energy infrastructure [12].

Scientist V. Klyushnikov pays a considerable attention to the issues of space industrialization, step-by-step deployment of industrial production there and, in particular, extraction (including a description of technological specificities) of non-renewable natural resources required for knowledge-intensive industries – osmium, palladium, platinum, rhenium, rhodium, ruthenium, etc. [9].

It should be emphasized that a consideration of ways of solution for the scientific issue raised in the article is limited to the works of the listed authors. No suggestions in regards to this issue have been revealed in reputable sources in English. Thus, in spite of increasingly greater actuality and importance, scientific literature does not have any clear approaches to selection of manufactures (industries) for their upcoming transfer into space. There can be hardly any doubt here that it is impossible and inappropriate to transfer all terrestrial production to near space. For instance, it would be optimal to transfer power industry not as an entire industry but just a part of it that is required for manufacture of aluminum, steel, and other industrial produce. However, to have electric lamps lighting and electric stoves working in terrestrial homes, an appropriate part of power industry should remain on the planet, as energy delivery from space (except for solar radiation) may be ineffective and extremely dangerous.

Method Description

The methodology proposed for assessing feasibility of industry transfer into near space is based on an approach that uses eight criteria and corresponding indicators with unequal influence of their specific weights (weight coefficients). The following criteria are posturized for a selection of specific industries:

- hazardous substances emissions;
- resources available in near space;
- quality (competitive capacity) of manufactured products (goods, services);
- required labor resources;
- place of location;
- energy capacity;
- manufacturing process duration;
- manufacturing area.

Based on the result of calculations according to the suggested method, it is necessary to determine a practicability index for transferring production to near space (expressed as a percentage).

The eight criteria required for an assessment have the same number of respective indicators (Table 2). Notably, half of them (those required to calculate criteria such as "Hazardous substances emissions", "Place of location", "Energy capacity", "Manufacturing area") are quantitative and available in open information sources (primarily internal for companies), including statistical ones; these are calculated quite easily. The values of the remaining four indicators (for the criteria "Available resources in near space", "Quality (competitive capacity) of manufactured products (goods, services)", "Required labor resources", "Manufacturing process duration") are determined by experts at an enterprise itself (with the expert evaluation method).

Table 2 – Matrix of industry selection for their transfer to near space

Criterion	Indicator corresponding to the criterion	Criterion weighting coefficient K	Adjustment (estimated) factor δ					Product $K_n \times \delta_n$
			1	0.75	0.5	0.25	0	
1. Hazardous substances emissions	Hazardous substances emissions to atmospheric air from stationary sources, t/year	0.2	More than 5,000	1,001–5,000	101–1,000	11–100	Less than 10	$K_1 \times \delta_1$
2. Resources availability in near space	Degree of resources and raw materials availability (mineral resources, solar energy, materials, etc.) in near space that are required for a full-scale implementation of production activities without engaging terrestrial resources	0.15	Abundant	Sufficient	Uncommon	Rarely found	Completely absent	$K_2 \times \delta_2$
3. Quality (competitive capacity) of manufactured products (goods, services)	Improved specifications (including service life) of the products (goods, services) manufactured in space due to natural environmental properties (zero gravity, deep vacuum, technological cleanliness, etc.)	0.15	Paramount (dozens of times)	Considerable (5–10 times)	Insignificant (1–2 times)	No changes	Decreased	$K_3 \times \delta_3$
4. Required labor resources	Approximate percentage of employees that are to be transported to near space together with the manufacturing facility, in order to provide the enterprise activities (under the condition of maximum manufacturing process robot automation), % of the current headcount	0.1	Less than 10	11–25	26–50	51–75	76–100	$K_4 \times \delta_4$
5. Place of location	Air quality index (IQA) in the region where the terrestrial manufacturing facilities of the enterprise are located, units	0.1	Heavily polluted (more than 200)	Moderately polluted (151–200)	Slightly polluted (101–150)	Less polluted (51–100)	Practically unpolluted (no more than 50)	$K_5 \times \delta_5$
6. Energy capacity	Full energy capacity of the enterprise, MW	0.1	More than 100	51–100	11–50	1–10	Less than 1	$K_6 \times \delta_6$
7. Manufacturing process duration	Average duration of processing raw materials (materials, semi-finished products, component parts) into finished products (services) on Earth within the existing principal activity, days	0.1	More than 30	21–30	11–20	1–10	Less than 1	$K_7 \times \delta_7$
8. Manufacturing area	Area of manufacturing facilities (premises) of the enterprise, thous. m^2	0.1	More than 50	21–50	6–20	1–5	Less than 1	$K_8 \times \delta_8$
Total		1						

The practicability index for transferring production facilities to near space is calculated using the following formula (1):

$$I = \sum_{n=1}^{8} K_n \times \delta_n \times 100\ \%, \quad (1)$$

where I – practicability index for transferring production to near space (within a range between 0 and 100 %);

n – sequential number of a criterion;

K – weighting coefficient of a criterion that reflects its priority degree;

δ – adjustment (estimated) coefficient dependent on the allocation of the actual value for the enterprise to a specific category according to the scale.

All criteria have weighting coefficient K that reflects their importance (priority) in selection of industries for a transfer to space. The most significant (which is also confirmed in their writings by representatives of the scientific community in this field A. Unitsky, A. Babayan, V. Klushnikov, N. Sinyuk) is the criterion "Hazardous substances emissions" that is calculated by determination of the amount of hazardous substance emissions to atmospheric air from stationary sources (tons per year) as presently the most widely used and adequate statistical indicator in the field of environmental protection regarding emissions of hazardous substances with a value of 0.2 (or 20 %).

For instance, legal entities in the Republic of Belarus (except for small businesses) annually provide the Ministry of Natural Resources and Environmental Protection with such data in accordance with the form of state statistical reporting 1-air "Reporting on Emissions of Pollutants and Carbon Dioxide to Atmospheric Air from Stationary Sources of Emissions", approved by the Resolution of the National Statistical Committee No. 122 dated December 10, 2019 [17]. Similarly, foreign statistical bodies monitor emissions of pollutants into the air in their countries (both on the whole and separately for solids, sulphur dioxide, carbon monoxide, nitrogen, hydrocarbons, non-methane volatile organic compounds, etc.), and carry out their quantitative analysis and assessment. Meanwhile, the actual practice demonstrates that the level of hazardous substance emissions into other components of the biosphere (lithosphere (land) and hydrosphere (water)) is much less often monitored, so there is no analytical data similar to the data on emissions into the air, in statistical compendiums and other open scientific sources.

Weighting factor K with an assigned value of 0.15 (average degree of significance) is defined for two criteria: "Resource availability in near space" and "Quality (competitive capacity) of manufactured products (goods, services)" that can be assessed by expertise using their respective indicators:

- "Degree of resources and raw materials availability (mineral resources, solar energy, materials, etc.) in near space that are required for a full-scale implementation of production activities without engaging terrestrial resources";
- "Improved specifications (including service life) of the products (goods, services) manufactured in space due to natural environmental properties (zero gravity, deep vacuum, technological cleanliness, etc.)".

The five remaining criteria ("Required labor resources", "Place of location", "Energy capacity", "Manufacturing process duration", and "Manufacturing area") have an equal minimal weighting coefficient K of 0.1 within the developed method.

Besides, dependent on the actual value of the indicator used for calculation, every criterion is assigned with a specific adjustment (estimated) coefficient δ according to the scale presented in Table 2.

Quantitative interval parameters for this scale are determined based on the data contained in the public domain [5, 18–20], with due account for global approaches to the classification of specific indicators used (e.g., [21]); they have been also identified logically and expertly based on the analysis of information provided by some companies and derived from other reference sources. Notably, five equal-step intervals between 0 and 1 are set (with a step of 0.25) to calculate the adjustment (estimated) coefficient δ. An assignment of coefficient 1 (maximum size) means the highest degree of practicability for transferring manufacture to space according to the criterion under consideration.

Thus, based on the defined adjustment (estimated) coefficient δ for each of the eight criteria, Table 2 is filled in; thereafter, the practicability index I for a transfer of manufacture to near space is calculated according to formula (1).

Based on the assessment carried out with the suggested method, one of the two decisions is taken currently:

- if index I exceeds 50 % (simple majority principle), a transfer of the manufacture to near space is deemed practicable (topical);
- if index I is equal to 50 % and less, a transfer of the manufacture to near space is deemed inefficient (untimely).

In any case, when comparing different manufactures (industries) for their possible relocation into space, this process can be more effective only for those with a higher value of index I.

Outcomes and Analysis

The suggested method (selection pattern) is informative and, at the same time, fundamental (from the author's point of view), since the criteria and indicators included in it are the most important factors in assessing practicability of an industry transfer into space on a global planetary scale.

To a certain extent, the indicators that correspond to the eight criteria integrate the environmental, energy, production, economic, and social components.

The financial and economic mechanism of relocation, as well as a number of criteria related to the economic solvency of enterprises and their ability to implement this large-scale process (the company market value, sales profitability, value of annual profit, etc.) can be taken into account only after a recommendation to transfer manufacturing facilities on the near-Earth orbit, with due account to the assessment outcome obtained within the suggested method. It is possible to use [22] as an economic model for establishing a practicability of relocation.

While applying the presented method for analysis and assessment by industry (type of economic activity), they should be systematically arranged according to the International Standard Industrial Classification.

The method (model) considered in this article is the author-developed; it will be tested in detail on some Belarusian and foreign industrial enterprises (real economy entities) while continuing scientific research in this field.

Conclusions and Future Work

The authors reiterate their previously stated position on the necessity for a rapid industrialization of near-Earth spaces and relocation of manufacture from planet Earth to near space due to the ever-increasing population, aggravated environmental situation, and depletion of natural resources. Thanks to a full-scale industrial development of near space, humanity will be able to:

- solve global environmental problems and challenges;
- remove hazardous industrial manufacture from the surface of Earth beyond its biosphere – to near-Earth orbits;
- live in comfort and safety on the planet in harmony with nature, etc.

While working out this issue, we revealed the absence of scientific papers focused on the selection of industries for their transfer to near space. The method suggested in the article includes eight criteria and the same number of indicators. It is aimed at calculation both at the micro-level (based on specific enterprises, with their actual statistical data, and using the expert assessment method) and at the mesolevel (based on specific industries with extrapolation and scaling).

It is planned to adapt and test the method for future application by its competent public administration bodies, public regional and international organizations (including those engaged in space exploration and solving problems in this field), enterprises of the real economy, in order to determine practicability of transferring manufactures (industries) to near space.

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UDC 537.613

Application of Magnetic Suspension in High-Speed Transport Systems

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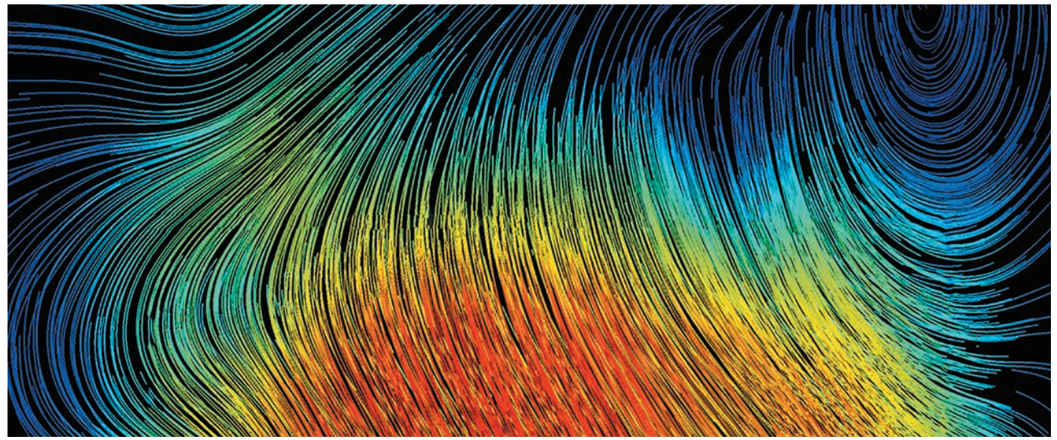
The possibility of using magnetic suspensions as part of a new generation of transport systems moving at a speed of 400 km/h and more has been studied. The power and dynamic features are presented, the design of a magnetic suspension adapted for use as part of the General Planetary Vehicle (GPV) is considered in detail, since it is one of the key elements of this geocosmic complex.

Keywords:
magnetic levitation, magnetic suspension, high-speed transport, General Planetary Vehicle (GPV), eddy current.



Introduction

A high-speed transport complex is a fundamentally new facility that requires the use of innovative technologies for supporting a transport trolley on a track structure. To implement it, it is necessary to develop a "trolley – track" pair that ensures movement at speeds above the permissible limit for a "wheel – rail" pair. The speed record on the rails belongs to the French experimental train TGV and equals to 575 km/h [1]. However, this may be a one-time case, since at this speed the current collector is connected to the contact wire through an electric arc. In addition, the wear of the equipment excludes regular operation. The "wheel – rail" pair for railway transport provides an economically advantageous cost of movement at speeds up to 400 km/h [2].

A further increase in speed is possible due to levitation, in particular, magnetic one, since when using wheels at speeds above 400 km/h during long-term operation, materials (for the manufacture of wheels and rails) with high yielding and strength are needed. The absence of physical contact in the "trolley – track" system assumes that a linear electric motor is used as a mover. The "trolley – track" system consists of two subsystems: a magnetic suspension and a linear electric motor.

Only the magnetic suspension is presented within the framework of this article. Levitation in a magnetic field can be arranged with the help of electromagnets, superconducting materials, and permanent magnets. Electromagnetic systems assume the presence of high-capacity power supply units and control systems. The option with superconductors requires significant energy costs to maintain the ultra-low temperature of power magnets. Since the most energy-efficient solution is important, the choice is made in favor of systems operating on permanent magnets.

Literature Review

There are several technologies in the world that provide magnetic levitation, which uses the effect of displacing a magnetic field from a superconductor, as well as feedback electromagnets and permanent magnet systems [3]. The use of electromagnets implies the presence of feedback amplifiers. This technology requires a large amount of non-ferrous metals. In addition, it is very energy-intensive [4]. Systems involving superconductors require low-temperature cooling, which causes significant energy consumption. Another serious disadvantage of electromagnetic and cryogenic systems is their dependence on uninterrupted power supply [5].

As a result, the least complicated and energy-intensive option was chosen – a system with permanent magnets. In this regard, Halbach assemblies attracted special attention [6]. However, the change in the resource of magnetic systems based on them has not been studied. In this article we are talking about magnetic systems without the use of Halbach arrays.

Goals and Objectives

The purpose of this work is to study various arrangements of permanent magnets and to identify the optimal configuration of the magnetic system that ensures stable levitation of the rotor in the field of permanent magnets. The solution of the problem has a wide range of applications. The priority use is the suspension of the rotors in the carrier system of the General Planetary Vehicle (GPV) [7].

Experimental Determination of the Magnetic Field Power Characteristic

- Fixing experimentally the power characteristic of the magnetic field of the permanent magnet N40 ($Nd_2Fe_{14}B$) with the size of 40 × 20 × 5 mm (Figure 1).
- Comparing the obtained indicators with the data of a mathematical model of the similar magnetic system.

Manufacturing of the Suspension Model

- Developing and manufacturing a model of an elementary cluster of the magnetic suspension system.
- Measuring experimentally the load capacity of the suspension, its transverse and directional stability.
- Developing a mathematical model of the created cluster and comparing the simulation results with experimental data.
- Adjusting the mathematical model taking into account the discrepancy between the values of the calculated and experimental data.

Working out the Design of the GPV Rotor Magnetic Suspension, as well as a Mathematical Model

- Proposing the design of the magnetic suspension of the GPV rotor.
- Working out a mathematical model of the static magnetic suspension of the GPV rotor.
- Working out a mathematical model of the dynamic magnetic suspension in the GPV rotor.
- Calculating the specific heat release of the magnetic suspension system.

Simulation of Magnetic Suspension

Interaction of Two Magnets

A graph of the dependence of the force repulsion of the analogous poles of neodymium magnets on the distance between them was experimentally obtained using a physical model. In addition, a mathematical model has been worked out. Figure 2 visualizes the magnetic field of a pair of rectangular magnets in the absence of external affects. Figure 3 shows the total power characteristic

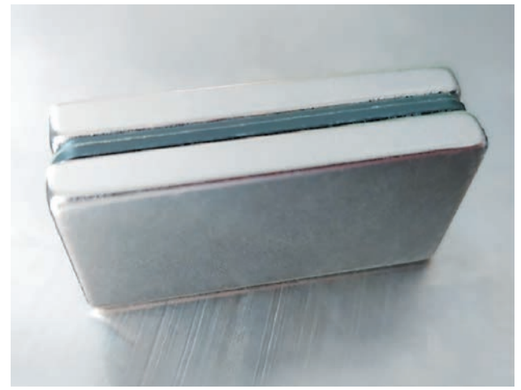


Figure 1 – Magnets N40 ($Nd_2Fe_{14}B$) of the size 40 × 20 × 5 mm

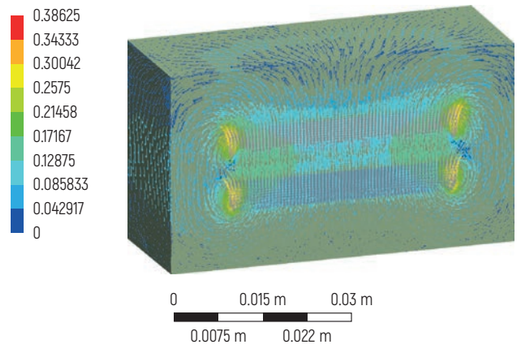


Figure 2 – Distribution of magnetic flow density in a system consisting of two magnets, T

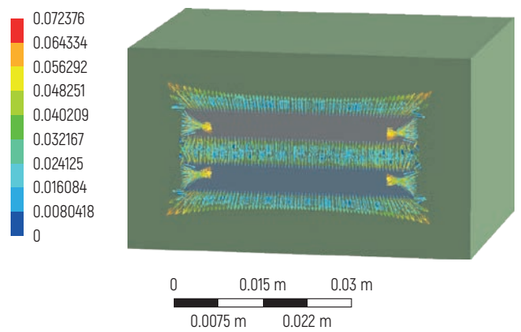


Figure 3 – Distribution of force vectors in a system consisting of two magnets, N

of the magnetic fields of two rectangular magnets oriented by opposite poles to each other. Figure 4 shows the dependence of the repulsive forces between two rectangular magnets on the distance between them. The simulation results are shown in Table 1.

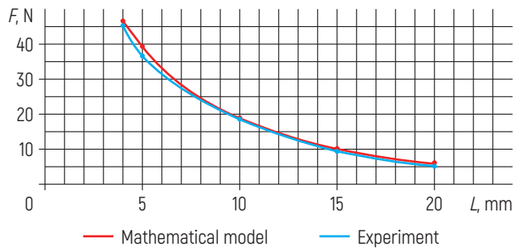


Figure 4 – Characteristics of the force field of a permanent magnet

Table 1 – Characteristics of the force field of a permanent magnet

Distance, mm	Force, N (stand)	Force, N (model)
4	45	47.02
5	37	39.41
10	18	18.32
15	9	10.04
20	5	6.57

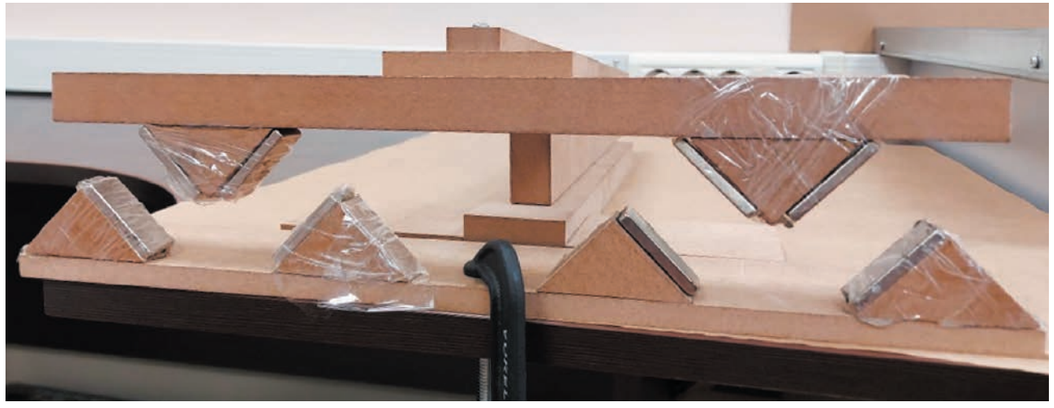


Figure 5 – Model of the track structure cluster

Conclusion: as a result of the analysis of the data obtained, it was found that the mathematical model reflects reality rather accurately. The margin of error is less than 5 %.

Magnetic Suspension Model

For experimental verification of the operability of the magnetic suspension, a model of a self-stabilizing elementary cluster of a track structure and a levitating trolley was designed and manufactured (Figure 5).

Figure 6 shows a map of the distribution of forces caused by the interaction of the magnetic fields of individual magnets in the system.

As a result of the mutual impact of the fields of individual magnets on each other, the directions of the force lines have changed – zones of their weak and strong concentration have appeared. In Figure 7, areas of increasing magnetic flow concentration are shown in red; areas of decreasing concentration are shown in blue.

Table 2 presents the information obtained experimentally using computer simulation.

In the line "Physical model" of Table 2, the indicators identified experimentally by means of a desktop model are presented. The levitating part was loaded with metal hangers, which were subsequently weighed up on laboratory scales. Lateral forces were measured by an electronic dynamometer. The line "Mathematical model" reflects the results of computer modeling in the ANSYS 2021R1 environment.

Conclusion: experimentally, it was possible to recreate an active pair of a fragment of a track structure and a levitating trolley. The discrepancy between the data of the experiment and the mathematical model was no more than 5 %.

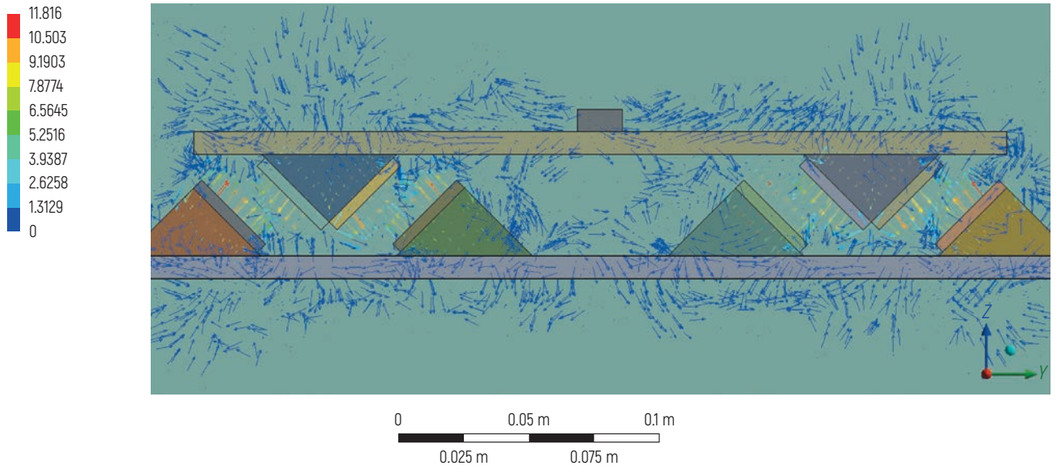


Figure 6 – Distribution of force vectors in a magnetic cluster, N

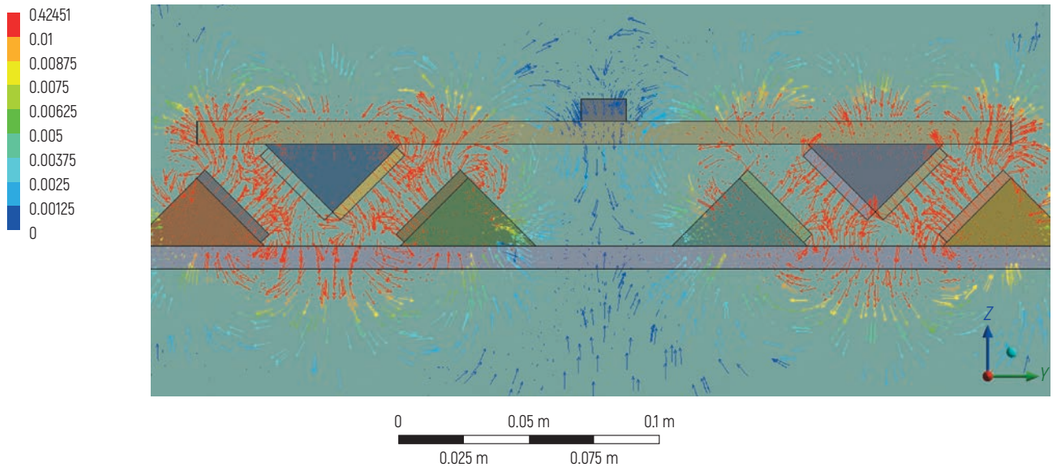


Figure 7 – Distribution of magnetic flow density, T

Table 2 – Discrepancy between experimental and computer simulation data

Object of research	Payload capacity, g	Minimum lateral destabilizing effect without payload, kgf	Minimum lateral destabilizing effect with payload, kgf
Physical model	1,002	0.07	0.208
Mathematical model	1,040.23	0.072	0.218
Error rate, %	3.79	3.76	4.65

Structure of the Magnetic Suspension in the GPV Rotor

One of the possible versions of the design of the rotor magnetic suspension in a system of permanent magnetic fields is considered. The cross section of the rotor, magnetic system, and linear motors is shown in Figure 8.

Figure 9 shows a fragment of the GPV rotor. Above and below there are power magnets that accept the lifting force from the flywheel. The remaining magnets stabilize the rotor and prevent its contact with the channel walls.

Figure 10 shows a fragment of a stator with magnetic suspension elements.

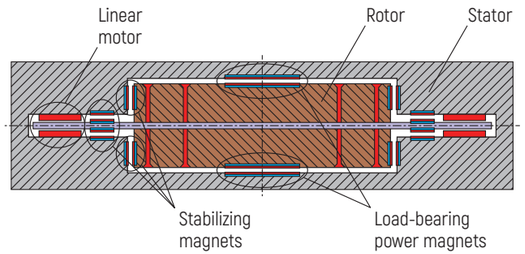


Figure 8 – GPV rotor design

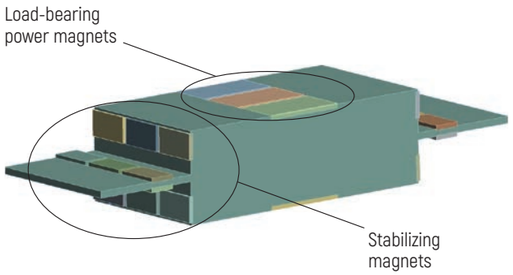


Figure 9 – GPV rotor design

Calculation of the Payload Capacity of the Magnetic System

During the calculation, the rotor material is specified as K76 steel. The yield strength is 850 N/mm^2. There were 10 separate forces acting on the flywheel from the magnetic system. Figure 11 schematically shows a chart of the forces accepted by the rotor from the side of the GPV stator magnets (the figures indicate the numerical parameters of forces in Newtons; the colors of the magnet and the force it causes are the same).

The distribution of magnetic flow densities in a separate magnetic suspension cluster is shown in Figures 12–14.

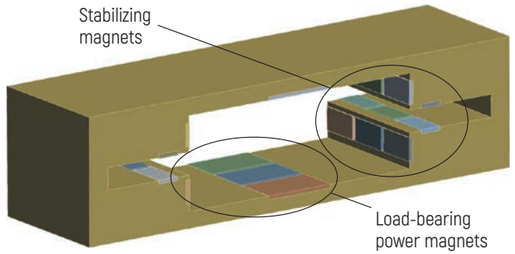


Figure 10 – GPV stator design

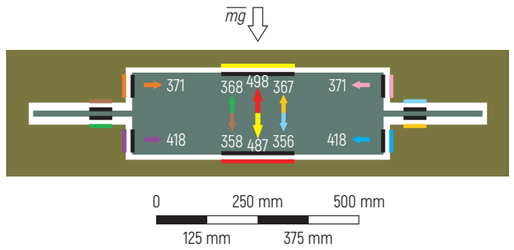


Figure 11 – Chart of the forces perceived by the rotor from the side of the GPV stator magnets, N

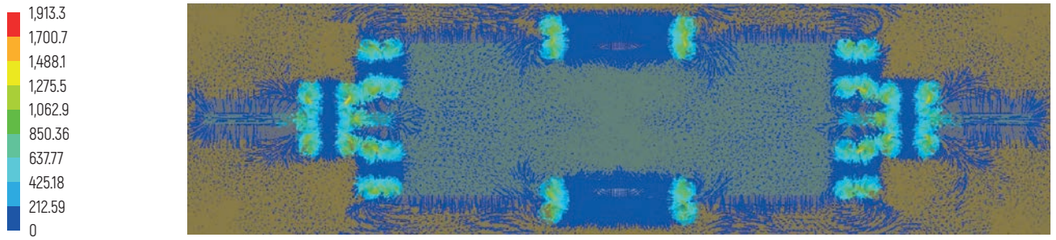


Figure 12 – Magnetic flow distribution chart in suspension (cross section), mT

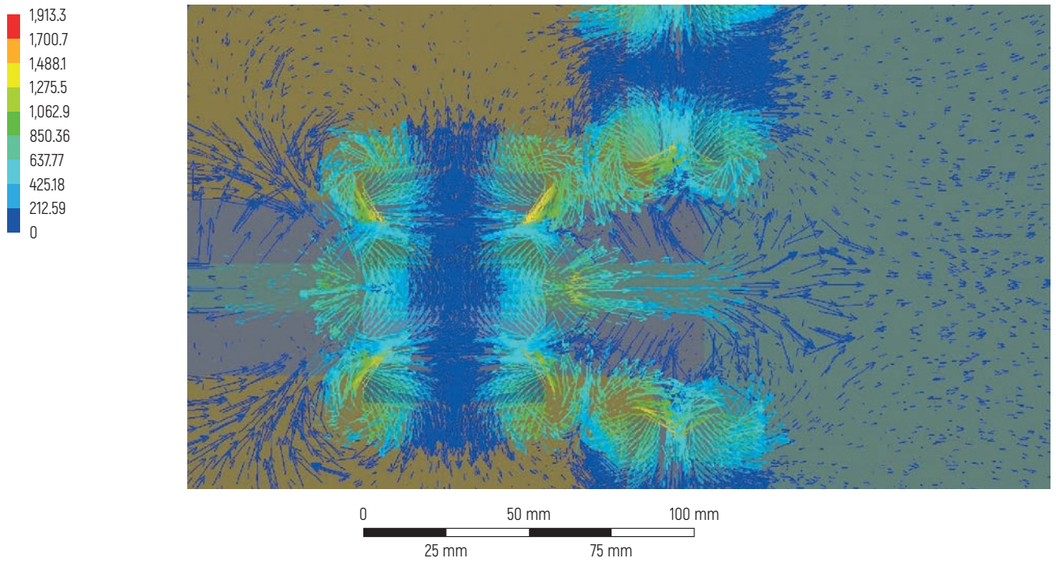


Figure 13 – Chart of distribution of magnetic flows in the stabilizing systems of magnets, mT

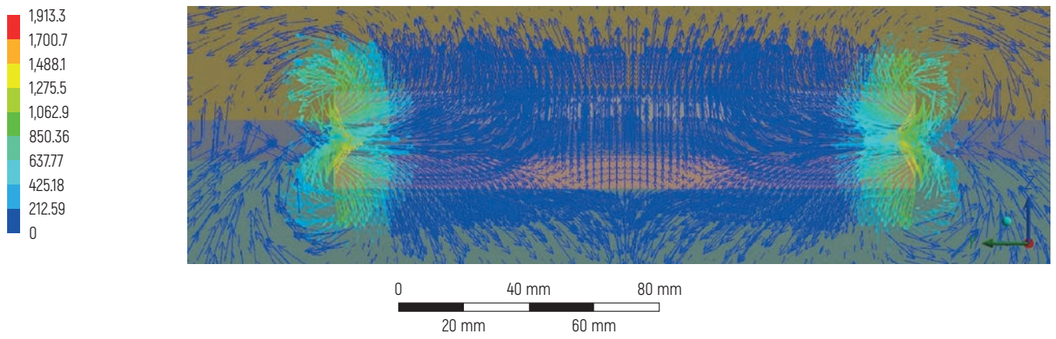


Figure 14 – Chart of distribution of magnetic flows in load-bearing systems of magnets, mT

The resulting force acting on the rotor from the side of the magnetic system (provided there are no external impacts, with the exception of gravity (mg)) is determined to be equal to 30 N and directed upwards (Figure 15).

The specific payload capacity of the system is 12,330 N/m, or 1,257 kgf/m. With the specific weight of the flywheels and the shell being 250, 225, and 200 kg/m, respectively, the maximum payload weight is 582 kg/m. The actual payload capacity is 500 kg/m.

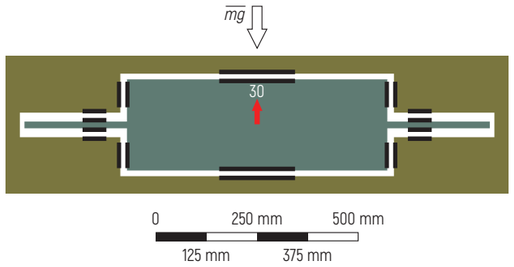


Figure 15 – Resulting force in static mode, N

Scale Model of Magnetic Suspension Fragment

Figures 16, 17 show a section of the magnetic suspension model.

The array of sections holding magnets is a magnetic suspension (Figure 18).

In the process of developing the model, the magnetic stabilizer system was modified. The model provides for the possibility of installing various configurations and layouts of magnets in order to select the most stable and least material-intensive design.

Calculation of the Amount of Heat Disposed to Ensure the Operating Temperature of Magnets

When moving, the rotor and the load-bearing magnets will heat up from the action of eddy currents. Neodymium magnets lose their magnetic force at temperatures above 70 °C. For ferrite magnets, the critical mark is 280 °C. Al-Ni-Co and Sm-Co magnets operate under the conditions up to 550 °C and are manufactured on the basis of the Al-Ni-Co-Fe alloy. The advantage of Al-Ni-Co-Fe magnets is a high temperature stability (up to 550 °C). However, the magnets Al-Ni-Co, Sm-Co are easily demagnetized due to external impacts, therefore the choice has fallen on $Nd_2Fe_{14}B$ magnets.

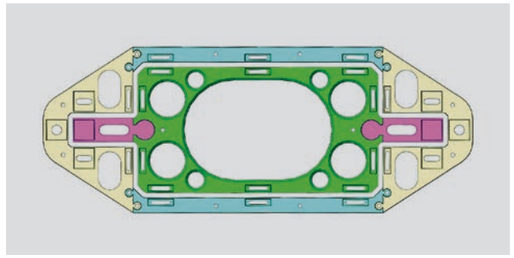


Figure 16 – Section of the GPV magnetic suspension

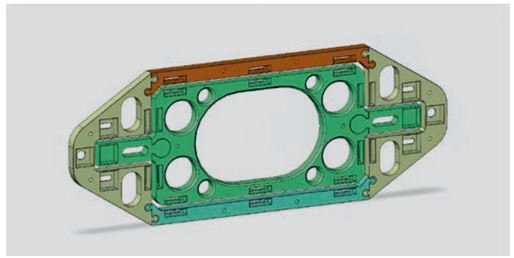


Figure 17 – Visualization of 3D model of the GPV magnetic suspension section

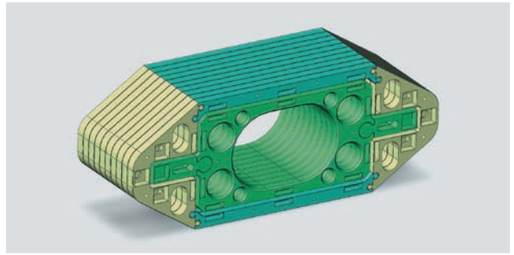


Figure 18 – Visualization of the GPV magnetic suspension fragment

The temperature of the GPV stator is calculated with the following input data:

- speed of the rotor relatively to the stator – 12,000 m/s;
- magnet size – 180 × 10,000 × 10 mm;
- type of magnets – N40 (magnetic induction 1,250 × 10^{-3} T);
- stator material – electrical steel of grade 3311;
- heat capacity of stator material – 500 J/(kg · °C);
- stator mass – 200 kg/m;
- specific electric resistance – 9.9 × 10^{-8} Ω/m;
- stator wall thickness – 2 mm;
- clearance between rotor magnets – 300 mm;
- clearance between rotor magnet and stator – 10 mm;
- driving time – 6,500 s.

Figure 19 shows a diagram of eddy currents induced in the GPV stator by moving rotor magnets. The magnetic induction feature is assumed as corresponding to a pulsating magnetic field with a constant clearance between the rotor and the stator and value $B(r)$ depending on one coordinate:

$$d_z = B(r)\sin\omega t, \quad (1)$$

where B – the amplitude value of the induction field of permanent magnets, B = 1.25 T;

r – period of installation of magnets, m;

ω – cyclic frequency, ω = 9,547 rad/s;

t – time, t = 6,500 s.

This feature is adopted as a measure to simplify the calculation of the eddy current.

Calculations of eddy currents were carried out on the basis of the methodology presented and used in [3, 4]. Eddy currents are studied in the plane of the sheets of the stator core and are considered to be energized by a magnetic field with a magnetic induction feature specified according to (1).

Thermal heating of the stator is determined by energy losses according to the Joule – Lenz law. Energy losses can be calculated by the formula:

$$P_{eddy} = N\frac{1.64 d^2 f^2 B^2}{A\rho_v}, \quad (2)$$

where d – stator wall thickness, d = 2 mm;

f – frequency of field change, f = 1,165 Hz;

B – amplitude value of the induction field of permanent magnets, B = 1.25 T;

A – stator length, $A = 4 \times 10^7$ m;

ρ_v – specific volumetric resistance of stator material, $\rho_v = 9.9 \times 10^{-8}$ Ω/m;

N – number of stator fragments, $N = A/L = 4 \times 10^6$ pcs;

L – length of the isolated stator fragment, L = 10 m.

The energy of the losses will be converted into thermal energy. The power released in the stator volume is equal to:

$$P_{eddy} = 4 \times 10^6 \frac{1.64 \times 0.002^2 \times 1{,}165^2 \times 1.25^2}{4 \times 10^7 \times 9.9 \times 10^{-8}} = 14 \times 10^6 \text{ J/s}.$$

The stator temperature change will be 0.74 °C/s.

Conclusion: a rotor moving at the speed of 12 km/s (in the absence of cooling) will induce eddy currents in the stator, which will heat the stator by 0.74 °C within 1 s. The need for a cooling system is obvious. It is important to find ways to improve the efficiency of the magnetic suspension system.

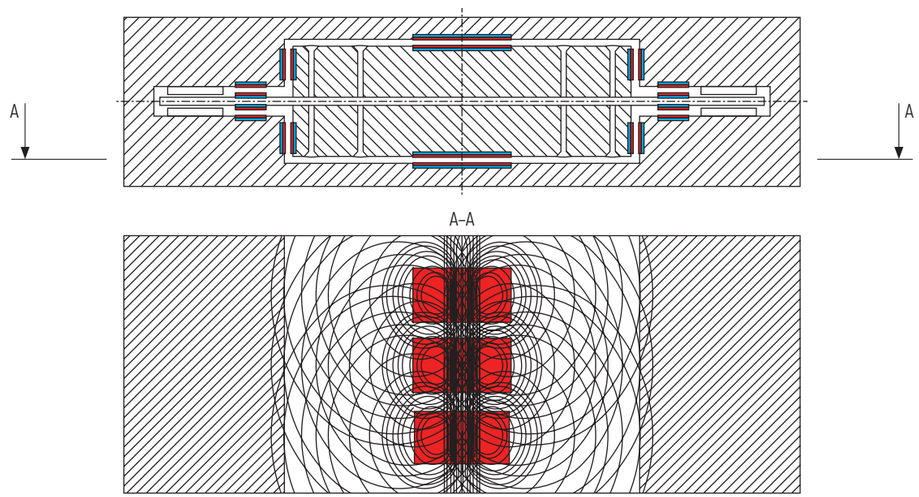


Figure 19 – Eddy currents in the GPV stator

Conclusions and Future Work

One of the promising areas of development is the study of Halbach magnetic arrays. The use of magnetic arrays is possible in the magnetic suspension of the GPV flywheels to enhance and change the magnetic field pattern. At the next stages, it is planned to create a large-scale physical model of a fragment of a load-bearing magnetic suspension and a full-size functional prototype.

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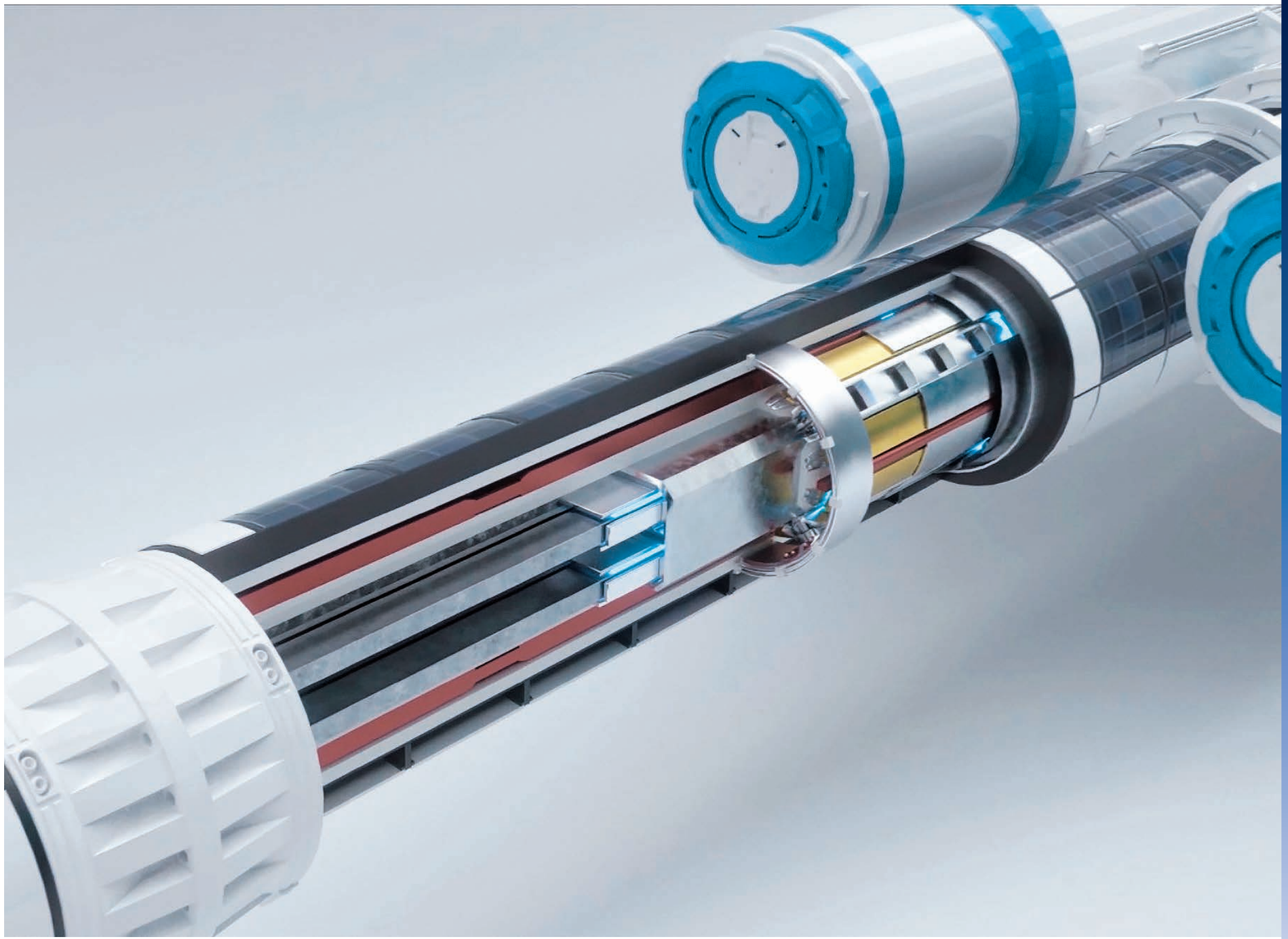

UDC 67.03

Applicability of Wood-Based Eco-Materials in Structural Elements of the General Planetary Vehicle

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Wood is in the focus of attention as an eco-material that can be used at objects that are part of the General Planetary Vehicle (GPV). Based on literary sources we give applicability options for wood, as well as analyze its characteristics with regard to other most common materials. It is proposed to introduce an eco-orientation factor based on materials properties as a comparative assessment of their impact on the environment. By reference to the presented criteria, the environmental effectiveness for application of wood-based eco-materials in the construction of the GPV facilities is shown. The directions for further technological development for obtaining new wood-based materials, providing an eco-orientation increase in the GPV operation as a whole, have been determined.

Keywords:
wood, eco-material, eco-orientation, General Planetary Vehicle (GPV), life cycle, assessment criterion, biofiber.

Introduction

In view of the global population growth and, as a consequence, an increase in the consumption level, leading to generation of bulk waste, today we face a critical problem of the efficient utilization of available resources in the production of goods. In this case the efficiency should be considered in the context of minimum impact on the environment. The development of the General Planetary Vehicle (GPV) is not an exception in keeping with this approach. During the construction of the GPV objects, various types of materials are used (metals, composite synthetic and ceramic materials) with different degrees of impact on nature. The GPV concept is built on an eco-oriented approach [1], based on the resulting reduction of the harmful impact on our planet at all stages of the GPV life cycle: development, operation, and disposal. At present, the GPV eco-orientation is focused on the operational component involving the use of materials that reduce resource consumption during the operation of the GPV objects. As the example, it is necessary to point out the preference in the choice of materials with a minimum specific weight, as well as those competent to withstand the resulting loads and consume the optimal amount of energy at the same time. However, due to the emphasis on the operational component of the GPV environmental compatibility, less attention is paid to other aspects: eco-orientation in the development and disposal of the GPV materials used. Reducing the weight of products to decrease energy consumption is only part of the overall GPV eco-orientation that practically does not affect the disposal of consumable materials and does not indicate the negative impact on the environment during the production process.

The problem of eco-orientation in the GPV implementation is the mandatory use of materials, the production process of which does not have a negative impact on wildlife. Ecologically, it is not rational to include aluminum alloys in the GPV gondolas, since the production of this chemical compound requires the expenditure of a large amount of Earth's resources (in particular, 1 kg of aluminum requires about 16 kW·h of energy, and 1 kg of steel – 9 kW·h). Now the materials that do not have a harmful effect on nature at the stage of release are being developed. Waste recycling is one example of the eco-orientation in development of materials that can be used for production of the GPV objects. It is also important to note naturally occurring materials: most of the stages of their production take place in the environment, i.e., in a natural way.

In turn, the environmental issue in the GPV disposal involves the necessity to introduce materials into the production process that do not lead to environmental pollution when destructed. Thus, most of the synthetic compounds in the GPV structures significantly reduce the weight of objects, however, the disposal of artificial components on Earth causes the generation of a significant amount of waste due to the insufficient development of the appropriate technologies. In this case, the materials disposed of in the human environment (leather, natural fabrics, wood) meet the conditions laid down.

Thus, the eco-orientation of all GPV objects requires a serious approach to the selection of materials subject to their full life cycle: at the stages of manufacture, operation, and disposal.

This work primarily focuses on validation of optimal raw materials for creating the GPV objects in the context of full eco-orientation that provides the comparative evaluation of various materials with respect to impact on the environment. It is proposed to make a point of wood and wood-based materials that differ in their environmental compatibility from other products (leather, natural fabrics, mushrooms) primarily by their physical and mechanical properties [2]. Due to similar qualities, wood is widely used in the furniture industry and construction. It is preferable to use wood-based eco-material in the structures of the GPV gondolas that will require about 0.01 mln tons of wood for production annually. This amount is determined based on the total mass of materials required for the GPV (30 mln tons) [3], average life of the GPV objects (30 years), and percentage rating of wood (1 %) to the total volume of materials in the GPV. Considering the fact that the annual wood increment on the Earth is about 6 bln tons [4], the amount of 0.01 mln tons will not have a significant effect on the scale of deforestation during the GPV construction.

Literature Review

Wood as a unique material takes attention of many scientists. It is positively called an eco-material, since such raw material is received and disposed with minimal impact on the environment. Scientific investigations accentuate the useful properties of wood that can be enhanced due to introduction of various technologies. Authors in [5, 6] show development of its optical parameters, in [7] analyze possibility of magnetizing. Similar features of wood material are achieved through special impregnations that should not harm nature. For example, a special alcohol composition has been developed to increase the fire resistance of wood [8]; it reduces inflammability – one of the disadvantages of wood. The magnetic properties of the eco-material in question are applicable in suspension devices of the GPV as the element of a magnetic, magnetic-liquid suspender, or a guide.

As a structural material, wood is outlined against other eco-materials (leather, natural fabrics, etc.). It can be used as a framework for filling with various materials [9]. Thus, it becomes possible to produce new ecological raw materials based on wood (wood-mineral and wood-metal) that are optimally appropriate for separate GPV units design.

The development of modern nanotechnologies also concerns wood. This material is considered as an object of energy storage and transmission using biofibers [5]. More and more information on the useful properties of wood component biofibers (Figure 1) is being accumulated with a view to create various materials [10, 11].

Many scientists regard wood not only as an engineering raw material but also as a material providing environmental clean up. Attention is paid to this direction in [12], which describes technologies for water purification by means of wood fibers.

Wood is analyzed as a conductor of water in [13]: the water permeability of fibers is studied (similar to water movement from roots to leaves in a tree). Thus, the water-transmitting properties of wood can be considered when designing the GPV filters to clean and deliver liquids to various complexes, including life support systems.

Day by day more and more wood-based materials are used, however, they still contain synthetic raw materials that significantly degrade the environmental properties of wood products. For example, reference [14] presents the furniture industry, where wood has a significant demand, and its disposal is an important point in the process, since demand for furniture increases every year. When creating the GPV objects, it is necessary to consider the severe consequences of development in the furniture industry: its hazardous industries management and widespread introduction of synthetic materials have led to environmental problems. To resolve the environmental problems arising from the wood products creation, it is proposed [15, 16] to reuse wood materials containing toxic components in the production processes, thereby reducing the harmful substances quantity at waste landfills. At the same time, the study [17] describes the use of more environmentally friendly adhesives for wood-based materials manufacture.

Based on the information studied, it can be concluded that the creation of wood-based eco-materials and their large-scale use in the GPV construction will increase the level of eco-orientation during operation and disposal of the geocosmic transport and infrastructure complex objects (Figure 2).

Figure 1 – Wood biofiber (variants)

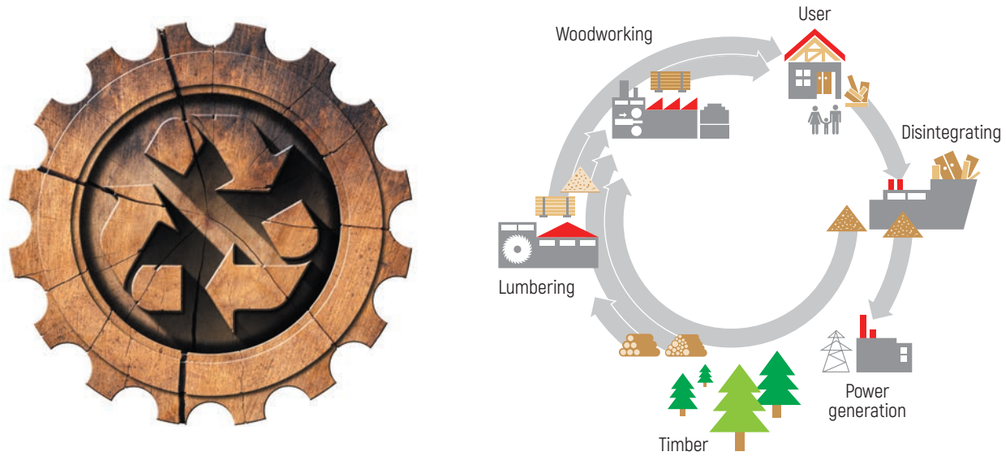

Figure 2 – Wood as an eco-material in the construction of the GPV objects

This approach is a global trend in the development of technologies, which allows us to rationally spend resources in the future to ensure the lives of a large number of people. The conclusion is shown in the form of a diagram (Figure 3). It does not show the entire list of eco-materials made of wood to be used in the GPV structural elements. Only the materials delivered for research are systematized. Based on the studied researches, it is important to pay attention to the fact that the physical, mechanical, chemical, and other properties of wood can be significantly improved, thereby expanding its use.

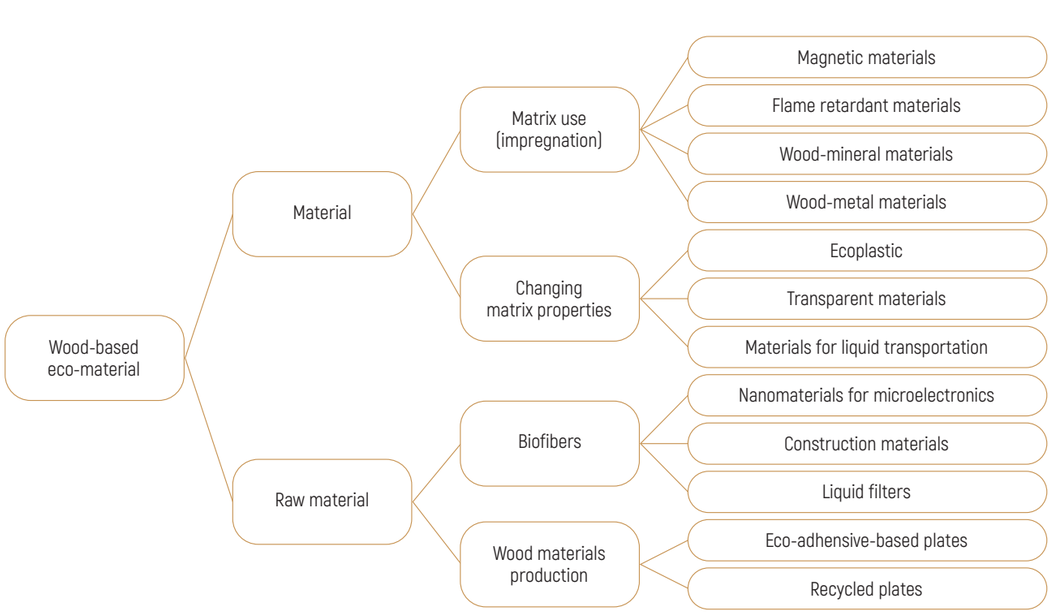

Figure 3 – Production of wood-based eco-materials

Method Description

The eco-orientation for inclusion of various materials in the GPV structural elements is proposed to be considered in the context of development, operation, and disposal of materials, thus analyzing the entire life cycle of the GPV objects. This approach is shown schematically in Figure 4.

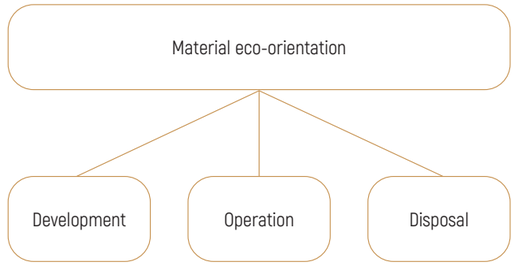

Figure 4 – Diagram of eco-material life-cycle stages

For a comparative analysis of various raw materials, the material eco-orientation coefficient (K) equal to the sum of the material eco-orientation coefficients of development (K_1), operation (K_2), and disposal (K_3) stages, i.e., determined by the dependency (1), is used:

$$K = K_1 + K_2 + K_3. \quad (1)$$

As criteria for eco-orientation evaluation of various materials it is necessary to calculate its own coefficient K for each stage, dependent on their physical and mechanical properties.

For the stage of material production, the main criterion should be considered as the cost per material unit, which reflects all the resources spent for its manufacture. Coefficient K_1 is determined by the dependency (2):

$$K_1 = \frac{C\sigma_b}{C_b\sigma}, \quad (2)$$

where C is the cost per material unit mass, USD;

C_b – cost per base material unit mass, USD;

σ – permissible compressive stress of material, Pa;

σ_b – permissible compressive stress of base material, Pa.

The main criterion for the operation stage of material is the specific weight of the material competent to withstand specified loads. As a basic characteristic, it is proposed to use the compressive stress σ as a parameter affecting the design data of the GPV structural elements [3]. Coefficient K_2 is determined by the dependency (3):

$$K_2 = \frac{\gamma\sigma_b}{\gamma_b\sigma}, \quad (3)$$

where γ is the specific weight of the material, kg/m^3;

γ_b – specific weight of the base material, kg/m^3.

For the disposal stage, the criterion for eco-orientation evaluation is the cost of bringing raw materials to the state of the basic material (difference in the cost of material and secondary raw materials), as well as the operating time of the product. Coefficient K_3 is determined by the dependency (4):

$$K_3 = \frac{(C - C_r)\,T_b}{(C_b - C_{r.b.})\,T}, \quad (4)$$

where C_r is the cost of secondary raw materials for the material, USD;

$C_{r.b.}$ – cost of secondary raw materials for the base material, USD;

T – lifetime of the material, years;

T_b – lifetime of the base material, years.

The specified coefficients will feature the environmental compatibility of raw materials, classifying its impact on the environment: the higher the coefficient, the greater the material impact on nature.

Results and Analysis

The author examined a few most common materials (wood, steel, aluminum alloy, concrete, glass, and composite material (fiberglass)), which have the values that make it possible to evaluate only their relative characteristics (Table).

As the key object of this research, wood was taken as a basic raw material. Input parameters based on published sources may vary. However, the main goal of the work is to consider the comparison methodology and evaluate the materials eco-orientation at different life cycle stages of the GPV products.

Table – Comparative data on materials

Characteristic \ Material	Wood	Steel	Aluminum alloy	Concrete (M300)	Glass	Fiberglass
Cost per 1 kg, USD	1.2	4	4.4	1.2	0.8	2.8
Permissible compressive stress, MPa	10	160	40	25	25	65
Specific weight, kg/m^3	500	7,800	2,700	2,400	2,500	1,800
Product lifetime, years	25	50	50	50	40	30
Cost per 1 kg of raw material, USD	0.6	0.24	1	0.4	0.2	0.75
Development (K_1)	1	0.21	0.92	0.4	0.27	0.36
Operation (K_2)	1	0.98	1.35	1.92	2	0.55
Disposal (K_3)	1	3.13	2.83	0.67	0.62	2.85
K	3	4.32	5.1	2.99	2.89	3.76

Conclusions and Future Work

The data presented in the Table show that concrete, wood, and glass have similar eco-orientation coefficients and minimal impact on the environment according to the proposed evaluation criteria.

The key conclusion of the study: wood-based eco-material can be used for various purposes (not only as a structural material) in the GPV objects. At the same time its use as a material is effective in the context of the minimum impact on the environment, that is corresponding to the general concept of the GPV development. It is useful to remember about the wood eco-material safe usage. The research analysis shows that in these terms good results are achieved due to the wide possibilities to change wood properties.

Thus, the further development in direction of using ecological wood material during construction of the GPV objects should be considered in the sense of new materials creation. Having unique features, they will significantly increase eco-orientation and thereby reduce the impact on the environment during the GPV objects construction.

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UDC 624.21.037:621.763

Composite Materials and Technologies for Manufacture of Overpass Structural Elements for the General Planetary Vehicle

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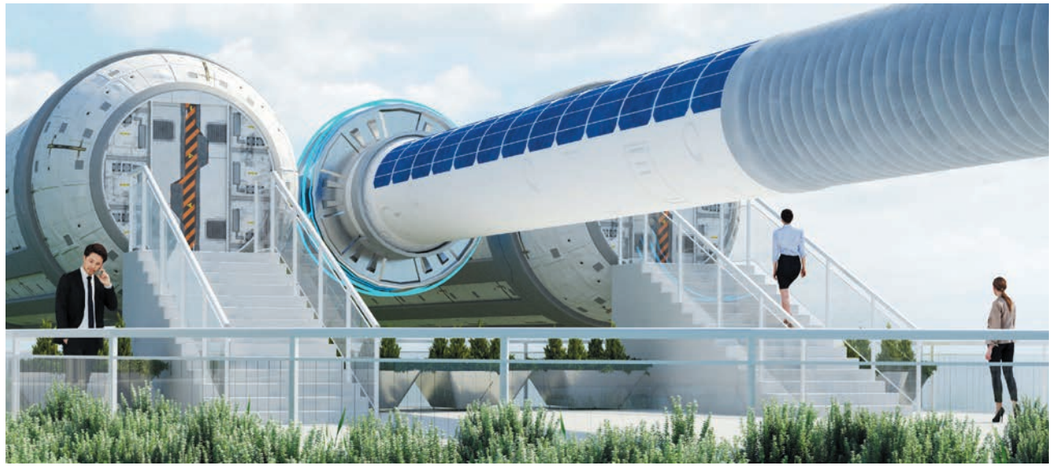
We have considered extrusion technologies for creating structural elements of large length that can be used in construction of the General Planetary Vehicle (GPV) overpass (uWay). We analyzed the influence of technological and design factors on physical and mechanical properties of composite materials employed.

Keywords:
extrusion, composite material, thermoplastic polymer, filler, physical and mechanical properties.



Introduction

The scale of constructing the General Planetary Vehicle (GPV) launch overpass (uWay) that would cover the Earth in the equatorial plane requires an introduction of extremely efficient technological processes that ensure high quality, optimal cost, and maximum productivity. The total length of the uWay, covering the Earth in the equatorial plane, is 40,076 km, of which approximately 20 % of the length is land sections, 80 % is maritime [1, 2].

While manufacturing supporting structures of the uWay, it is necessary to use materials with particularly high physical and mechanical characteristics. This precondition seems to be one of the most critical, since the overpass that contains various structural elements combined into a single prestressed supporting structure, when operated, should function as a span structure and a rail track for transport vehicles running in any operation mode, as well as accept vertical, longitudinal, and transverse loads and transfers them to the supports through the support and anchoring nodes [1, 2].

In manufacturing auxiliary structural elements of the overpass (cable channels, technological pipelines, enclosures for engineering networks, etc.), promising for use are general-purpose structural materials, among which plastics and composite materials are of particular interest. Their main advantages over traditional materials used in construction of transport facilities (steel and concrete) are: lower density and, as a result, lower weight of the structure; high corrosion resistance; a possibility of maximum use of secondary resources in their production; low production costs.

At the same time, the most effective method in manufacture of elements of a significant length made of plastics and composite materials is extrusion that ensures continuous production, maximum productivity, high material utilization rate, and transversal dimensional stability.

Research Methodology

One of the promising ways in this direction is creation of composite materials based on thermoplastic polymers and hybrid fillers, in particular, a combination of mineral and organic particles with different size levels [3–6]. This approach allows a development of new composite materials and products with a specific set of required properties. Thus, a combination of fine wood waste and mineral fillers provides conditions for formation of a homogeneous material structure resulting in a composite with high strength properties.

Wood possesses a more developed surface and a capillary porous system even when compared to such promising mineral fillers as porous perlites, obsidians, and aggloporites. The use of wood materials makes it possible to reach high (up to 85 % by volume) degrees of filling with technological properties maintained virtually the same; while with mineral fillers, the properties of composites decrease already at a filling degree of 30 % by weight (15–20 % by volume), and their processability deteriorates. At low degrees of filling (up to 20 % by weight), the saving in polymer is surpassed by the costs of the filler processing and composition preparation.

The said advantages are due to the fact that wood, being a natural polymer composite, is characterized by almost 100-percent compatibility with polymers, in contrast to mineral substances; its organic nature ensures coefficients of thermal expansion close to that of the binder, which results in an additional hardening effect due to a decrease in thermal stresses. On the contrary, when mineral powders are used, the liquid phase of the binder is distributed over the surface by thin films that further transform into a solid amorphous state. This transition is accompanied by an increase in density and a sharp decrease in volume, which entails an appearance of internal stresses that reach, in certain circumstances, 30–45 MPa. In such case, the higher is the surface energy of the filler, its rigidity, and the rigidity of the polymer binder, the stronger is the stress.

The presence of reactive groups in the macromolecules of the wood substance facilitates interaction of wood with a binder, which determines its wide chemical modification. Strong, yet less hard than polymers, wood fibers significantly reduce equipment wear that manifests itself in processing highly filled polymers; they are also less susceptible to destruction due to their good deformability [7, 8]. At the same time, the combination of wood and mineral particles makes it possible to form composites with improved performance properties. Their extremely efficient combination is in the range of 1 : (0.25 ÷ 0.5). Increasing the content of dispersed particles in the composite leads to decreased properties (especially strength) that is associated with an increase in the surface area of the filler particles, which requires an increased binder consumption. A rational content of dispersed fillers (hydrolysis lignin, grinding dust, and fine rubber, α-phosphosemihydrate calcium sulfate, fly ash, and bentonite) is about 8–20 wt. %. In addition, the use of fibrous fillers (fiberglass, cords) in the manufacture of composites is a promising approach that provides the latter with impact and cracking resistance.

Outcomes and Analysis

The mechanism for increasing strength characteristics of composites is determined, on the one hand, by the reinforcing effect of coarse particles in the macrovolumes of the composite, and, on the other, by a denser and more structured packing of filler particles in the composite (Table). It is likely that this approach also contributes to a structural modification of a polymer with a mineral filler in local microvolumes of the polymer interlayer, which provides an increase in the binder crystallization rate in the interparticle interaction zone.

The use of dispersed additives in the composite also makes it possible to enhance thermal stability of the composite during processing, especially characteristic of composites with α-phosphosemihydrate calcium sulfate and bentonite. This is confirmed by information about the loss of mass of the studied compositions on graphs obtained using derivatographs (Figure 1). Their analysis shows that the beginning of the mass decrease temperature in a composition with a dispersed additive shifts from 170 °C to 290 °C. Besides, these additives, in combination with fire retardant additives, improve fire resistance of the resulting material [9].

Table – Density of composites with combined fillers

Composites*	Density, kg/m^3
CW + PVC + PP	1,100/990
CW + FA + PP	1,240
CW + PHS + PVC	1,300
CW + GD + PVC	1,240
CW + FR + PVC	1,150

* CW – crushed wood; PVC – polyvinyl chloride; PP – polypropylene; FA – fly ash; PHS – α-phosphosemihydrate calcium sulfate; GD – grinding dust; FR – fine rubber.

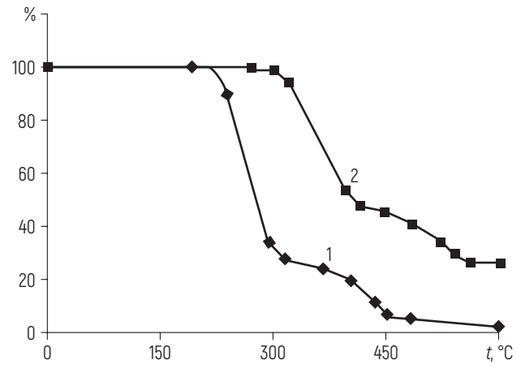


Figure 1 – Derivatograph curves:
1 – for pure composites;
2 – with added α-phosphosemihydrate calcium sulfate

Preliminary experiments have shown that processing of highly filled wood-polymer composites by extrusion is difficult because of their ultimate compaction in the extrusion spiral channel that leads to a sharp increase in friction forces along contact surfaces of the forming bodies

and internal interparticle friction. At the same time, there is a decrease present in the adhesive contact between wood and polymer, which is characteristic of PVC-based composites. Simultaneously, while forming bulk shaped products, the choice in favor of PVC is determined by its excellent dimensional stability and a high level of physical and mechanical properties in the composite system. One of the most important, yet little studied aspects in the formation of such composites is presented by tribotechnological features of extrusion processing. Therefore, it is extremely important to take into account the stated processes immediately at the "wood – thermoplastic" interface, which provides a possibility to adjust purposefully frictional and rheological properties in the wood-polymer system. This requirement seems to be a prerequisite for a stable extrusion process for highly filled composites. It is also obvious that, to solve this problem, a set of technological techniques is required that implements both triboeological and structural characteristics during extrusion formation of a wood-polymer system.

It has been established that plasticization of wood and polymer boundary layers in a "binder – filler" system is achieved due to a redistribution of the plasticizing substance previously introduced into wood particles. The redistribution effect is determined by the impact of the force and temperature fields during the extrusion process. The analysis of experimental studies makes it possible to draw a conclusion about the efficiency of wood particles modification with esters of orthophthalic acid [10].

It has been demonstrated that the efficiency of the use of orthophthalic acid esters is determined by their plasticizing effect on wood within the boundary layer in a composition with PVC. As a result, the energy consumed to compact wood without destroying its structure are reduced when the mixture moves in the extrusion spiral channel, which is facilitated by a decrease of up to 30 % in the force of plasticized wood compaction as compared to natural wood.

Based on the results of experimental studies carried out at V.A. Belyi Metal Polymer Research Institute of National Academy of Sciences of Belarus (MPRI), we have developed a technology for producing molded products by a worm extrusion technique. Due to their organic nature and good compatibility with polymers, wood fibers contribute to obtaining high filling rates in composites (up to 70–75 % by weight) and, consequently, respective operational properties.

Wide technical possibilities provided by the technology developed at the MPRI [10–12] make it possible to obtain products varying both in their profile shape and in purpose (Figure 2).

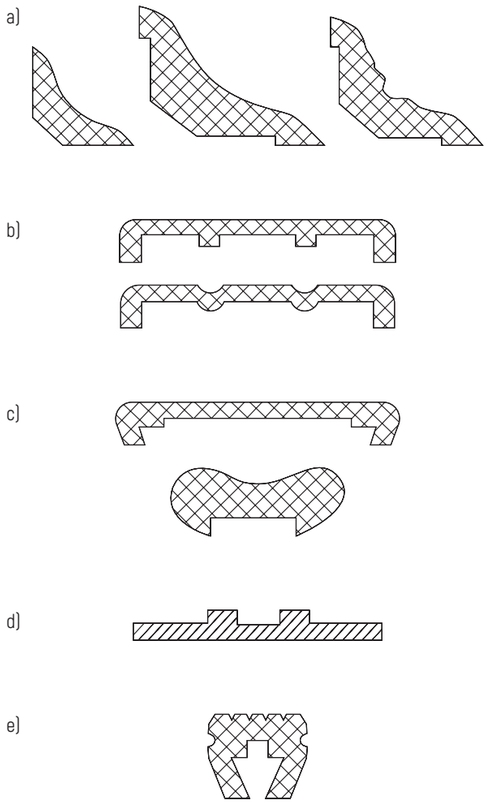


Figure 2 – Typical designs of wood-polymer molded products:
a – baseboards; b – cover plates; c – handrails;
d – scraper conveyor guide;
e – slide bearing for a rollerless belt conveyor

Conclusions and Future Work

Considering the above, it is possible to propose a high-performance method of manufacturing lengthy structural elements for the uWay. The basis of this technique is shaping of elements by means of extrusion; a wide group of composites based on thermoplastic polymers and hybrid fillers (mineral and organic particles) are used as necessary materials physical and mechanical properties whereof are efficiently controlled by technological modes of extrusion and introduction of target additives. Taken together, the described method can provide an optimal combination of operational properties and economic indicators when used within lengthy structural elements of such a complex object as the uWay.

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UDC 624.21.037:620.179.1

Innovative Technologies of Non-Destructive Testing and Technical Diagnostics for the General Planetary Vehicle Overpass Rails

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Two approaches have been considered for solving the problems of non-destructive testing and diagnostics for overpass rails of the General Planetary Vehicle (GPV). To localize discontinuities in the surface of rail frame elements, an advanced ultrasonic method is proposed that combines probe pulse laser excitation and their contactless registration with electromagnetic acoustic transducers. In the course of the work, the conclusion has been drawn: diagnostics of qualitative changes in the state of the railhead itself (rolling surface) of rail structures assembled from ribbon elements (strips) is more effective due to the use of technologies based on vibroacoustic methods.

Keywords:
laser ultrasound, optoacoustics, non-contact control techniques, vibroacoustics.

Introduction

General Planetary Vehicle (GPV) launch overpass (uWay) is a takeoff and landing, energy, and communication overpass hub for geocosmic transportations.

The uWay elements (for instance, a rail-string track structure for Unitsky String Transport (uST) and the uNet network [1]) are used for the GPV operation by means of providing electrical recharging, passengers and cargo, takeoff, landing, unloading, transfer of spatial products and solar energy accumulated in space, as well as maintenance and repair.

Besides, the following transport infrastructure elements of the uNet network are located in the overpass area:

- hypervelocity complex in forevacuum tunnel (speed up to 1,500 km/h);
- high-speed complex (speed up to 600 km/h);
- urban complex (speed up to 150 km/h);
- electric power transmission lines;
- communication lines.

High requirements to reliability, durability, and safety of the uWay, as well as rails, engineering networks, and its other structural elements, put forward specific requirements to the use of efficient control methods and diagnostic tools that allow for maximum precision in troubleshooting of possible defects.

The total length of the uWay, covering the Earth in the equatorial plane, is 40,076 km, of which approximately 20 % of the length is land sections, 80 % is maritime [1, 2]. Consequently, it is especially important to introduce diagnostic methods that make it possible to implement continuous non-contact remote defect and damage trouble-shooting.

The importance of choosing and implementing an efficient diagnostic system is determined, among other things, by the design solutions of the uWay consisting of various elements combined into an integral prestressed supporting structure that functions, in the process of its operation, as a superstructure and a rail track for vehicles moving in any operation modes; it also accepts vertical, longitudinal, and transverse loads and transfers them to the supports through the supporting and anchoring nodes [1, 2].

Research Methodology

The extended geometry of the framework elements of string rails makes it possible to excite core modes in them, i.e., elastic waves with a specific frequency that propagate over considerable distances from the source. Such waves can be registered by a set of transducers located at a specified distance along a lengthy component. The registered signals contain information about structural defects present in the material, its homogeneity, incipient fractures, cracks, etc.

One of the most rapidly developing areas of advanced non-destructive testing is laser ultrasound. Excitation of probing ultrasonic pulses occurs as a result of energy absorption of a nanosecond-long laser pulse. The absorption coefficient of metals in the visible and near infrared ranges is more than 10^4 cm^{-1}. As a result, the radiation penetration depth is limited to tens of nanometers. The laser energy is converted into heat with the diffusion rate during the laser pulse at approximately 1 μm. Thermal expansion of a thin near-surface layer excites volumetric and, when focused, surface acoustic pulses. A specific feature of laser-excited ultrasonic pulses is their shape with a pronounced compression phase and a wide frequency band covering more than two decades, with an upper limit exceeding 50 MHz [3]. This bandwidth allows detection of inhomogeneities, including incipient cracks larger than 50 μm in the longitudinal direction. The ultrasonic pulses can be registered with traditional contact techniques using piezoelectric transducers. However, a significant drawback of these transducers is associated with the need to ensure acoustic contact with a controlled object wherefore layers of liquid or gel are used, with a thickness that is difficult to control. At the same time, optical methods are available where single laser sources are used that allow contactless recording of ultrasound in a wide frequency band [4, 5]. The disadvantage of such solutions is a high cost and complexity of the system installation that is compensated for in this case by a high value and criticality of the controlled object.

Outcomes and Analysis

Taking into account the design specificity of the rails, the head (rolling surface) whereof in one of the versions consists of vertically oriented ribbon elements (strips) assembled into a block that are mounted on the ribs within the framework, the use of ultrasonic control techniques (including laser ones) is possible only directly for framework lengthy elements.

The above taken into account, registration techniques have currently been developed for diagnostics of rail framework elements that use advanced electromagnetic acoustic transducers sensitive to the alternating electromagnetic field that occurs in ferromagnetic materials as a result of the magnetostrictive effect [6–8]. The advantage of this technique is its simplicity, relatively low cost, and good information content for solving problems of non-contact non-destructive testing and diagnostics.

Simultaneously, for diagnostics of a railhead assembled from ribbon elements, it is of interest to control the noise level during a vehicle movement by means of a multichannel system for collecting and analyzing vibroacoustic signals with implemented narrow-band spectral processing based on the fast Fourier transform (FFT analysis), as well as vibration by means of a vibration measuring equipment (accelerometers). An accelerometer is installed directly in vehicles and carries out continuous non-contact measurements when their wheels interact with controlled objects.

The vibration measuring equipment provides the following parameters:

- frequency bandwidths for measuring values in octave frequency bands in the range of 1–63 Hz and 1/3-octave frequency bands in the range of 0.8–80 Hz;
- measurement of vibration acceleration levels within 0.1–10 m/s^2 over the entire spectrum in octave and 1/3-octave frequency bands with averaging (integration) time constants between 1 s and 10 s;
- measurement of current, maximum, and minimum (during the measurement) values of mean square levels, equivalent (in energy) mean square levels of absolute values of vibration accelerations in m/s^2 or their logarithmic levels in dB over the entire range of octave and 1/3-octave frequency bands simultaneously along three directions of orthogonal axes (*X, Y, Z*) at one measurement point using one three-axis accelerometer or three separate accelerometers oriented along the axes (*X, Y, Z*);
- narrow-band spectral processing based on FFT analysis of spectra with high frequency details;
- analysis of ordinal (reverse) and resonance (proper) components in narrow-band FFT vibration spectra will make it possible to implement an integrated approach to solving the problem of high-precision continuous remote diagnostics (with a reference to coordinates) of track structures within the uWay, which will ensure minimizing the risks of emergency situations related to a technical state of elements within the "vehicle steel wheel – rail steel head" system.

Conclusions and Future Work

Based on the above, we can propose an efficient approach to organizing a system for remote continuous non-contact diagnostics and non-destructive testing of the uWay rails based on two directions: the use of laser ultrasound for framework elements and a vibroacoustic technique for the assembled rolling surface (head) of the rails. The introduction of these technologies will make it possible to guarantee safety of the uWay rail track at the level required for a safe operation of the large-scale structure under consideration.

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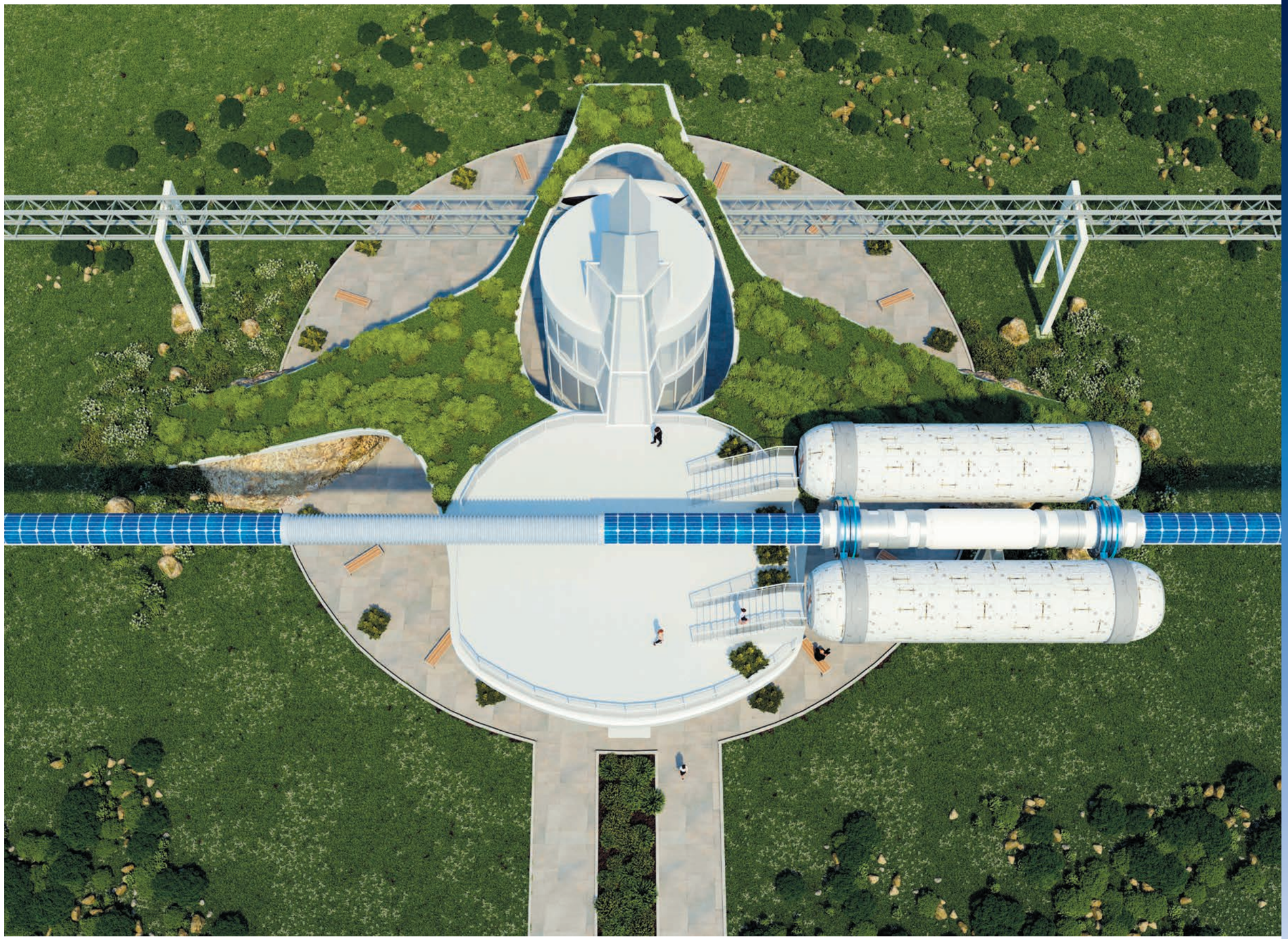

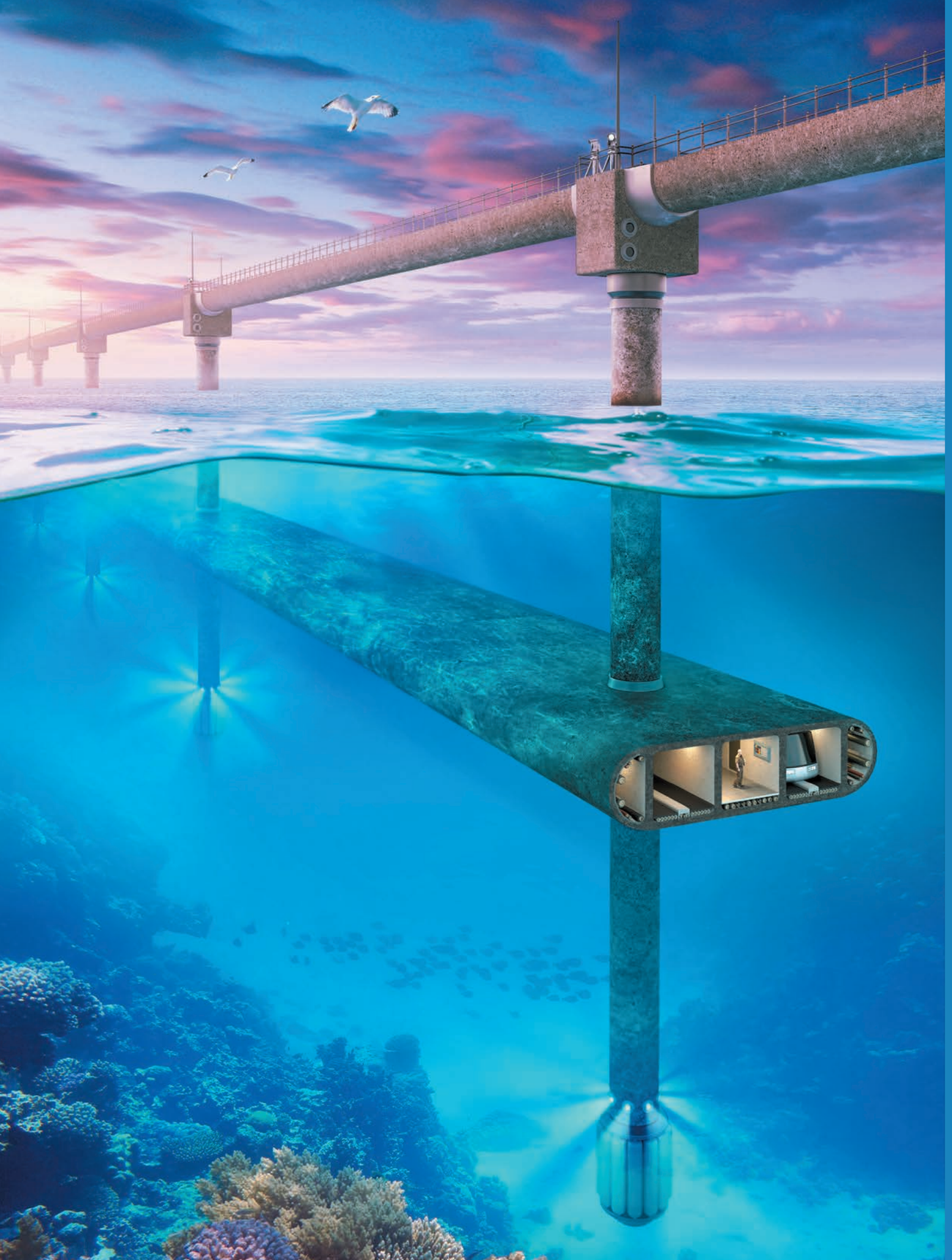

UDC 624.21.037:629.73

Dynamic Parameters of Submerged Floating Tunnel at Moving Loads

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Layout solutions to the ocean section of the General Planetary Vehicle (GPV) overpass (uWay) were given. Functional zoning was described and disturbing factors were defined that have an impact on the geometry of the floating tunnel. Requirements to evenness and stability of the track to carry hypervelocity vehicles were outlined. Internal disturbing factors in the form of moving cargo and passenger vehicles were determined. Effects of wave excitations and vertical responses from movement of a vehicle in the most loaded conditions for different-length spans were studied. Angles of twist of the floating tunnel subject to one-way traffic load were obtained. Stress in the tunnel walls initiated by passing vehicles was calculated.

Keywords:
General Planetary Vehicle (GPV), equatorial overpass, floating tunnel, hypervelocity transport, ocean section, disturbing factor.

Introduction

The General Planetary Vehicle (GPV) overpass (uWay) represents structure located along the equator line [1]. It combines different functions with the basic ones being passenger and cargo distribution, creation of land and ocean (marine) runway platforms along the equator, arrival/departure stations, as well as transport and logistics nodes.

There are external (marine currents, waves, wind, passing vessels, etc.) and internal factors that determine the geometry of water section on the route. The main internal factor is the traveling of vehicles, which, in total, produces an impact on the geometry and position of the submerged floating tunnel. Available research on the geometry of floating tunnels [2–4] are aimed at studying the impact of external factors, excluding the internal ones. For the use of such structures as highways, this is enough, but an integrated approach is needed to the design of a floating tunnel due to different requirements for structural elements. The most rigid requirements are imposed on the hypervelocity transport complex, which is due to super-high travel speed (over 1,000 km/h), safety precautions during transportation of passengers in forevacuum tunnels, and extremely high sensitivity to evenness of the track structure.

Mutual location of transport track complexes is considered the key aspect when drafting distribution of loads on the floating tunnel, which requires in-depth elaboration of the layout of the equatorial overpass.

Design and Layout Solutions and Arrangement of Loads on the Floating Tunnel

Figure 1 demonstrates two-dimensional schematic representation of recommended structural layout of the submerged floating tunnel acting as a runway for the GPV.

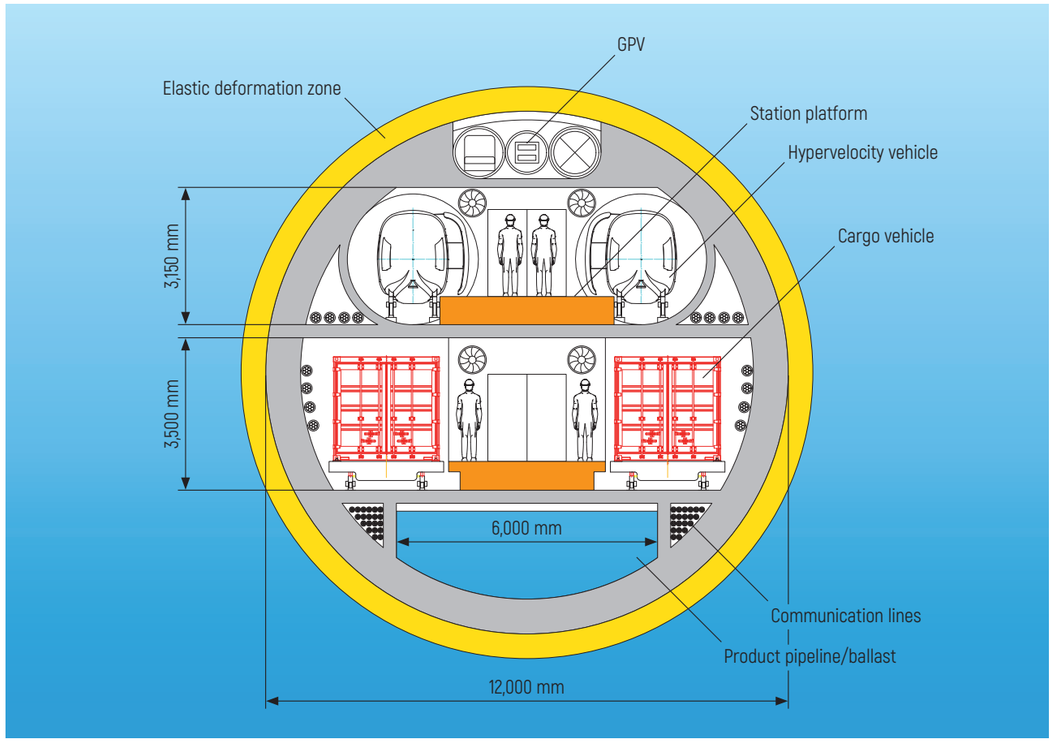

Figure 1 – Variant of layout solution to the ocean section of the submerged floating overpass in the area of boarding station

The floating overpass is geometrically divided into four functional areas. The central lower part has a product pipeline/ballast required to adjust floatability of the structure and fresh water supply; the sectional area is 11 m^2 [5]. Since ballast water flows continuously, it is taken as a static continuous load and was not considered in the calculation of wave excitations. Communication compartments are located at the edges of the ballast compartment. There is an area of cargo vehicles above – the primary exciting load. Above the cargo compartments, there are the tunnels designed for movement of forevacuum hypervelocity vehicles.

The structure proposed is characterized by symmetrical layout, which makes it possible to neglect the direction of movement. The upper part has a lodgment for reception and launch of the GPV with an area for boarding and loading of transport compartments.

The primary structural components of internal elements is reinforced concrete, which provides required strength and weight of the tunnel. The bearing concrete wall has an internal diameter of 12 m and general thickness of 0.6 m (Figure 2).

The tube of forevacuum tunnels is split by internal partitions of reinforced concrete. The space behind the platforms and boarding compartments in the sectional direction is used as a passage for evacuation and maintenance of the structure without changing the section, which ensures constant rigidity of the tunnel throughout the entire span. As the elastic deformation zone consists of foam material and it is sufficient to use a thin anticorrosive waterproof coating [6], their parameters were neglected in the calculation as being insignificant.

The proposed variant of the structure (at average sea water density in the equatorial region of 1,020 kg/m^3) has a weight of 115.3 t/rm. If using concrete with a density of 2,500 kg/m^3 as the main structural material, its reduced area (to ensure zero floatability) will be 46 m^2 (excluding compensation by liquid ballast).

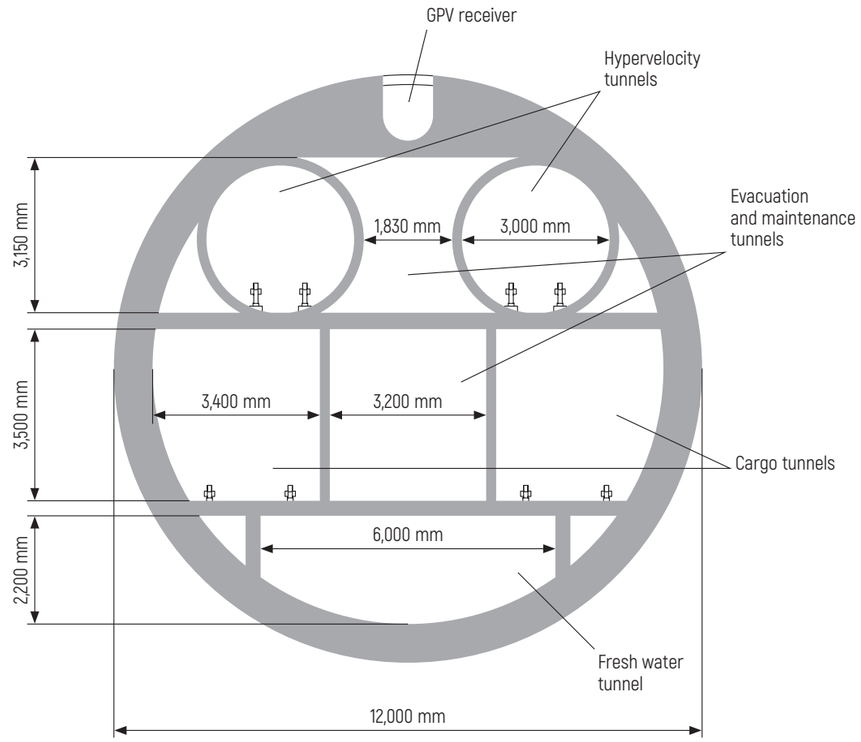

Figure 2 – Variant of layout solution to the ocean section of the submerged floating overpass in the inter-span section

We propose special high-strength concrete with a fiber filler, having a Young's modulus of 30 GPa, for the pipes. To avoid cracking, the outer casing is compressed with longitudinal reinforcement, while the whole structure is stretched for stability and resistance to transverse loads and bending moments. This effect is achieved by segmenting the pipe and using different functionally prestressed string components in the structure. At the same time, the tunnel is protected against hydrostatic and hydrodynamic forces [5].

Due to the longitudinal direction of the currents at the equator and ensuring minimum floatability of the tunnel, its design provides for maximum span length; 400 m, 800 m, and 1,200 m are taken as design inter-support distances. These spacings guarantee the required rigidity and strength of the supporting part of the structure. The spans are formed by the ties going to the foundation anchors and the external excess load having impact on the tunnel – the thrusting force minus the tunnel weight – is directed upwards (unlike conventional overpasses) rather than downwards.

Analysis of the Impact of a Moving Vehicle on the Tunnel

Input data:

- concrete with Young's modulus of 30 GPa;
- tunnel diameter – 12 m;
- wall thickness – 0.6 m;
- length of fixed section (span) – 400 m, 800 m, 1,200 m;
- calculated weight – 115,300 kg/rm;
- density of water medium – 1,020 kg/m^3;
- calculated bending rigidity – 1.5 × 10^{10} kN/m;
- submersion depth of the tunnel – 50 m;
- form-resistance coefficient – 0.55 (long cylinder);
- weight of single loaded cargo vehicle – 54,000 kg;
- weight of single passenger vehicle – 10,000 kg;
- length of single hypervelocity vehicle – 12 m;
- length of single cargo vehicle – 22 m;
- frequency of traffic – 90 s;
- calculated speed of hypervelocity vehicle – 333 m/s (1,200 km/h);
- calculated speed of cargo vehicle – 41.7 m/s (150 km/h).

Assumptions:

- load from the vehicle has uniform distribution along the length of the span;
- vehicle travels at constant speed.

Figure 3 depicts a 2D diagram of the loads taken by the floating tunnel.

When traveling, the vehicles generate secondary forces of gravitation and inertia in both vertical and horizontal directions. Besides, off-center location of transport tunnels initiates a bending moment. The forces of gravitation and inertia that have an impact on the span can be expressed through the following equation:

$$F_t = -(P_k + ma) \sum_{E=ei}^{el} \delta(E_x - E),$$

where P_k – force of gravity;

m – weight of a moving vehicle;

a – acceleration vector;

δ – function of two variables (the Kronecker delta);

E_x – loaded section;

E – all sections from ei (initial) to el (last) subject to a moving load in a certain interval of time.

The calculation was carried out in the ANSYS Workbench software.

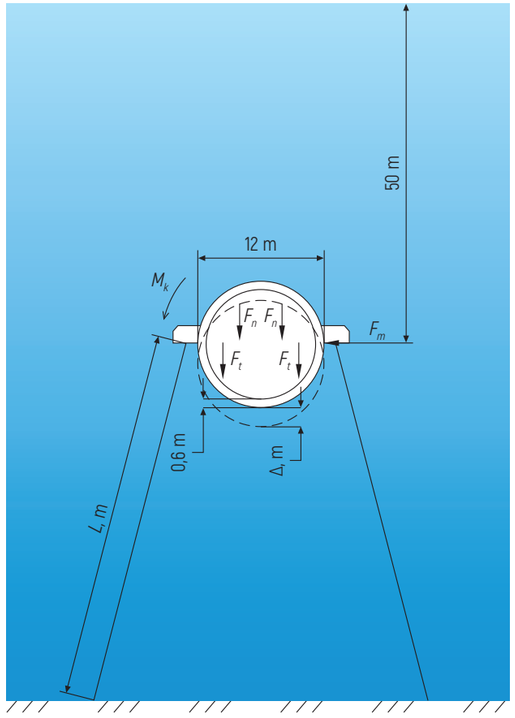

Figure 3 – 2D diagram of the loads taken by the floating tunnel

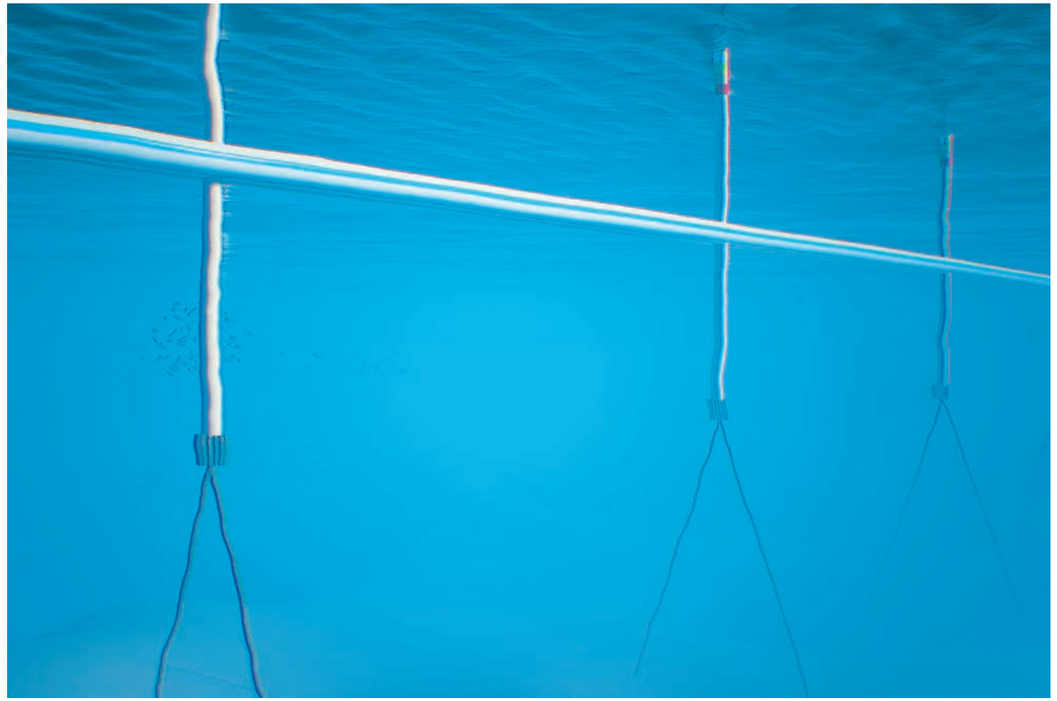

Figure 4 shows the general view of the analytical model of the ocean section of the submerged runway for the GPV.

External loads are represented by the pressure of 500,000 Pa on the tunnel walls at a 50-m depth. After the vehicles have passed, they return to original position

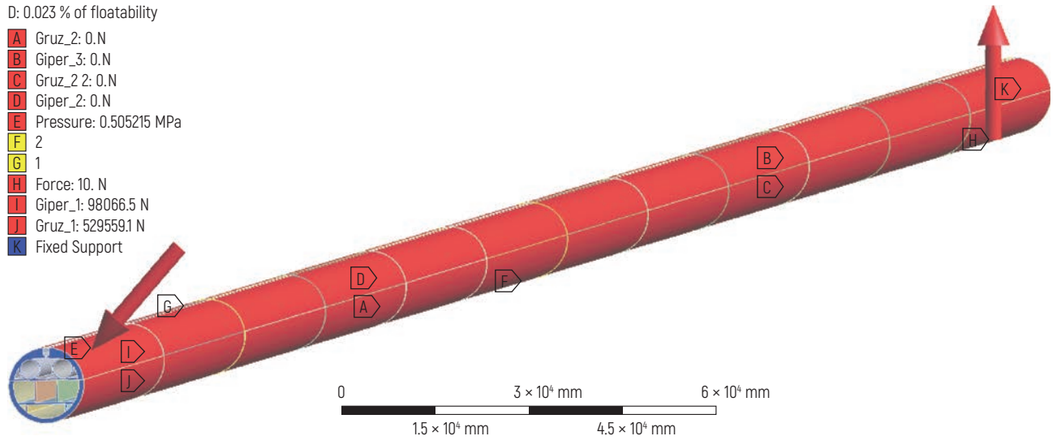

Figure 4 – General view of analytical model of the ocean section of the submerged runway for the GPV

due to positive floatability equal to 0.023 % of the total floatability of the tube, which corresponds to the traffic load. The impact from the transport (for bending moment simulation in the structure and determination of the angle of twist) was applied alternately in the center of the spans of each analytical modification from one side. The edges of the span section were fixed firmly. General view of the computational model, displaying a finite-element mesh, is shown in Figure 5.

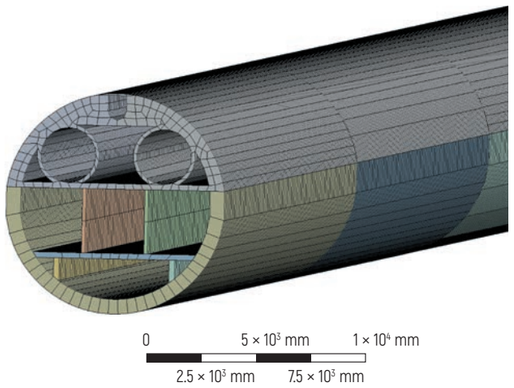

Figure 5 – General view of the computational model displaying a finite-element mesh

Calculation Results for Tunnel Flexure

During low-intensity movement, positive floatability of 0.023 % ensures a wave-like upward flexure of the structure by 3.2 mm at each span (Figure 6), which is a tolerable error during construction even at a 400-m span. However, this quantity was considered in the calculation to obtain more accurate results.

Preliminary calculations and studying of wave excitation effects and vertical responses form single vehicles [5] demonstrated that the values of vertical displacement (flexure) of the floating tunnel are less than 1 mm in the center of the span (Figure 7) regardless of the speed.

Displacement of the tunnel is significantly less compared to wave excitations caused by a storm or waterquake, which was also proved by other studies [7, 8]. Span flexure length during passage of a vehicle decreases with an increase in speed while its value remains almost unchanged regardless of the travel speed (within the error of 3 %).

Analysis of preliminary calculations enabled to review ultimate loads on a span and allow commissioning of container carriers uCont with a maximum weight of 54 tons. Further calculations were carried out for ultimate loads in case of simultaneous location of four vehicles (two cargo and two high-speed ones) in the center of the span (Figure 8). The results are given in Table 1 and Figure 9.

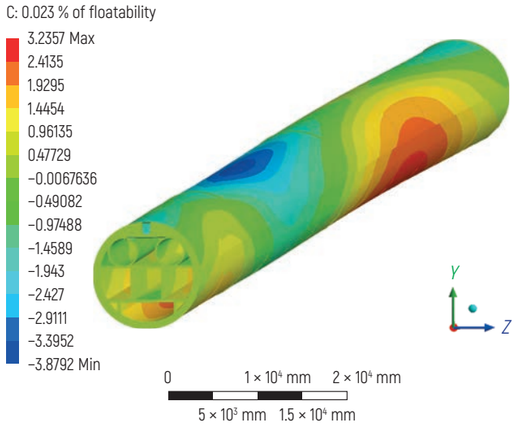

Figure 6 – Deformation along the *Y* axis under the impact of excessive upward force, mm

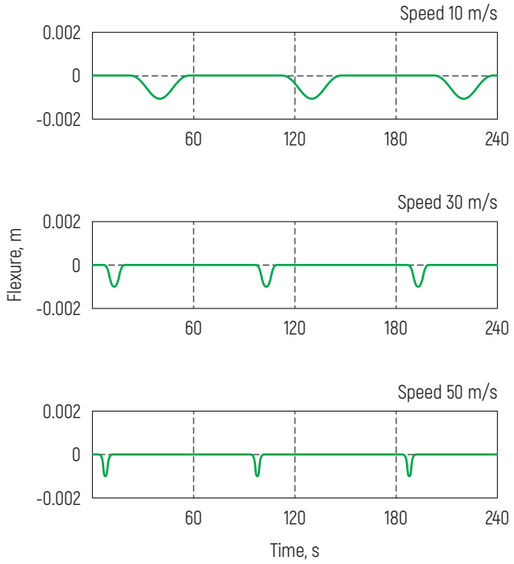

Figure 7 – Dependence plots of vertical displacements of the tunnel at a span vs 25-ton cargo transport travel speed

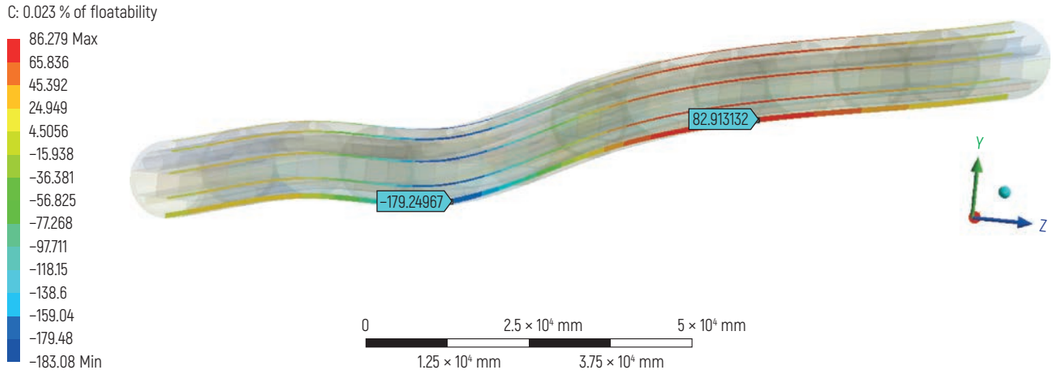

Figure 8 – Deformation along the *Y* axis of the 800-m span during passage of a vehicle, mm

Table 1 – Travel parameters of a hypervelocity vehicle at a vertical flexure of the floating tunnel caused by a passing vehicle with a total weight of 128 tons (with different length of spans)

Span length, m	Load application distance, m	Vertical flexure, mm	Slope, ‰	Height swings in case of 6-m support base, mm	Span passage time, s	Oscillation frequency, Hz
400	200	21	0.105	0.63	1.2	0.83
800	400	183	0.46	2.76	2.4	0.42
1,200	600	414	0.69	4.14	3.6	0.28

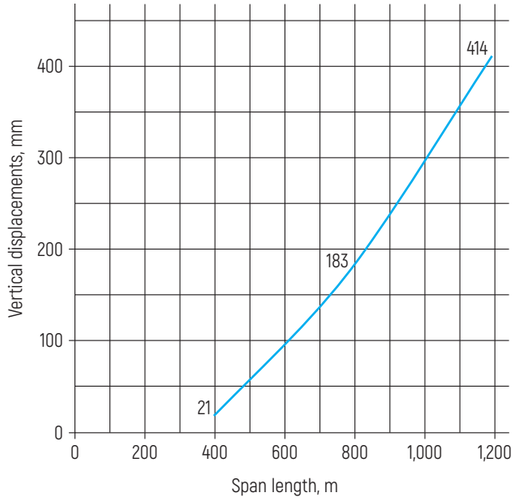

Figure 9 – Dependence plot of vertical displacements of the tunnel vs span length at simultaneous location of four vehicles with a total weight of 128 tons in the center of the span

Calculations showed that when the span length doubled (from 400 m to 800 m), the flexure increased by more than eight times (cubic dependence), further lengthening of the span by 1.5 times (from 800 m to 1,200 m) led to an increase in the flexure by 2.26 times (quadratic dependence). Determination of a more accurate dependence plot requires additional calculations with a lesser step of length change, however, for the purposes of these studies, the calculations performed are sufficient.

We do not recommend to have a 400-m span or shorter as, taking into account the travel time of the section equal to 1.2 s, the oscillation frequency of a vehicle reaches 0.83 Hz. According to [9], if the oscillation frequency exceeds 0.7 Hz, it can make passengers feel discomfort. At a span length of 1,200 m, the deflection of 414 mm will lead to its accumulation due to a low rate of relaxation because of small values of tunnel floatability (0.023 %), which will require either an increase of the vehicle movement frequency or an increase of tunnel floatability by 2.5 times. Consequently, based on the calculations, the optimal span length lies in the range of 700–900 m.

Calculation Results for Tunnel Twist

In case of one-way traffic, there is a bending moment that can break the symmetrical position of the tunnel, which changes the horizontal position of the railhead surfaces and lowers one rail relatively to the other. The inclination of the transport and the lateral displacement force that requires compensation are obtained as a negative consequence for the movement of hypervelocity vehicles.

The calculation was carried out for the co-directional movement of hypervelocity and cargo vehicles with a total weight of 64 tons at their intersection in the center of the span (Figure 10).

Calculation results (Table 2) revealed high torsional stability for all analytical length values of the spans and extremely insignificant angles of twist, which allows further neglection of this disturbing factor.

Calculation Results of Normal Tunnel Stresses During Vehicle Passage

During calculation, we also evaluated the loads taken by reinforced concrete as the primary structural component of the floating tunnel. Given possible asymmetrical impacts, the stresses were evaluated in both vertical (*Y* axis) and horizontal (*X* axis) sectional directions (Figures 11, 12, Table 3).

Figures 11, 12 show that the outer casing is compressed, excluding localized concentrators at the joints of the segments of the models. During construction, these places will require reinforcement, which will allow the structure to maintain operability for a standard lifetime if the service system is installed.

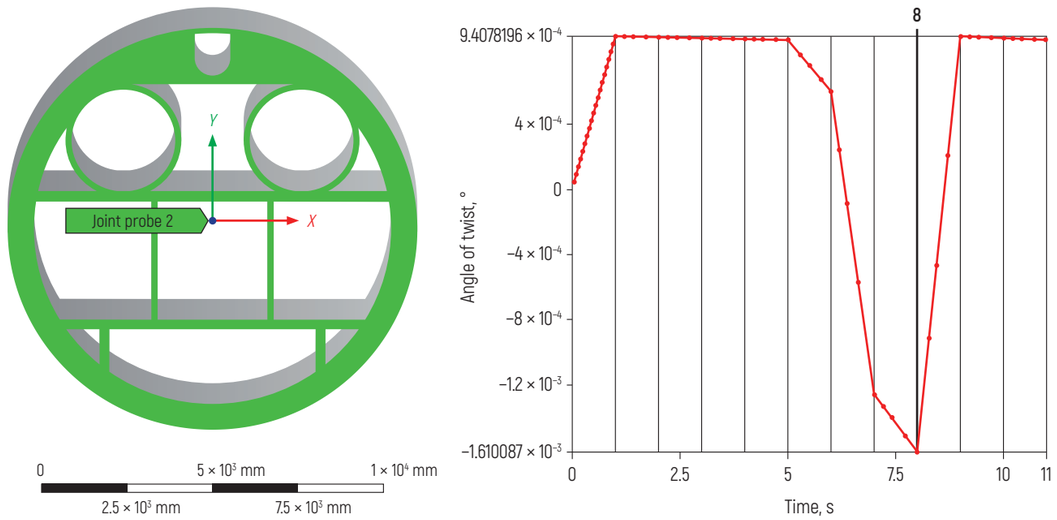

Figure 10 – Sectional twist of the tube during passage of a vehicle at the 800-m span

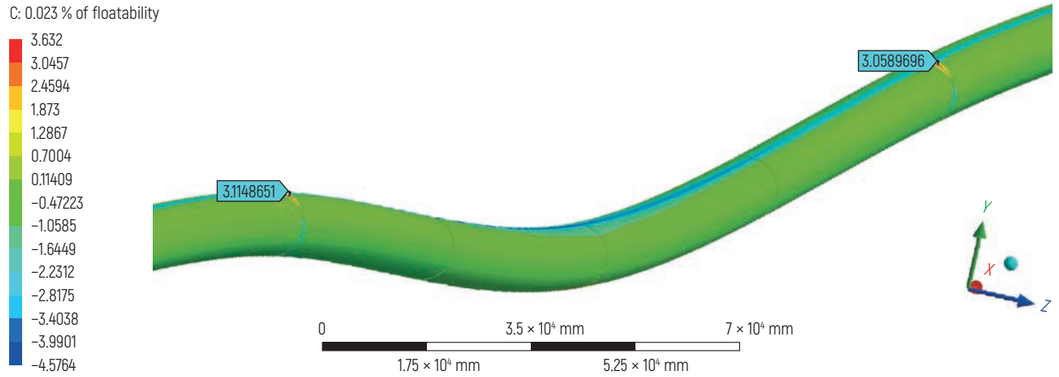

Figure 11 – Normal stresses along the *X* axis when a vehicle passes through the 800-m span, MPa

Figure 12 – Normal stresses along the *Y* axis when a vehicle passes through the center of the 800-m span, MPa

Table 2 – Parameters of the track structure of the hypervelocity tunnel with a twist of the floating tunnel caused by one-way passage of a vehicle with a total weight of 64 tons (with different length of spans)

Span length, m	Load application distance, m	Angle of twist, °	Rail height swings with a 1.5-m gauge, mm
400	200	0.001	0.026
800	400	0.0016	0.042
1,200	600	0.0024	0.063

Table 3 – Stress values in the floating tunnel during passage of a vehicle with a total weight of 128 tons (with different length of spans)

Span length, m	Load application distance, m	Normal stresses along the *X* axis, MPa	Normal stresses along the *Y* axis, MPa
400	200	3.5	3.9
800	400	3.6	4.8
1,200	600	4.6	4.2

Conclusions and Future Work

The main technical solutions in this article used in the design of the uWay can be implemented by means of modern technology in transport construction. The calculations show stability of the proposed layout and described structure to internal loads, which indicates technical capability to implement this project. Meanwhile, a complete consideration of all factors that have an impact on the equatorial overpass throughout its entire lifetime (during construction, commissioning, modernization, and disposal) will reduce the risks and increase the lifetime of the entire structure. Such approach makes it possible to carry out more in-depth elaboration of both individual components and the entire overpass in an interaction with traffic, natural, and man-triggered loads, which will enable to find more optimal technical and technological solutions for its creation.

The article delivers an in-depth calculation of the impact of passing vehicles on wave oscillations of the tunnel buried in the water at a depth of 50 m (below are leftovers of large ships and of hollows of the highest waves) to ensure smooth and comfortable movement of hypervelocity transport. This study requires further investigation, in which all external disturbing factors and their synergy will be considered. In addition, the authors proposed a variant of layout of the uWay and described the functionality of individual areas, which also needs technical and economic analysis.

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UDC 69.036.7

Designing and Construction of Intermediate Supports of the General Planetary Vehicle Overpass: Problems and Solutions

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About 100 structures with a height of more than 300 m have been built in the world; of these, only three bridges have supports above the specified mark. The highest support belongs to the Millau Viaduct Bridge (343 m).
When designing such large-scale structures, many problems arose. The authors of this article also faced similar challenges when developing the supports of the General Planetary Vehicle (GPV) equatorial overpass (uWay). In addition, it is also necessary to consider the specific loads due to the GPV operation. The shape of the intermediate support proposed by the authors is selected for optimal distribution of all external loads. Different versions of the bracing grid of intermediate supports, as well as the impact of the selected solutions on the weight, deformations, and natural frequencies of vibrations were analyzed.

Keywords:
General Planetary Vehicle (GPV), rotor motion trajectory, equatorial takeoff and landing overpass, supports of the uWay, loads on the uWay.

Introduction

As the name implies, the General Planetary Vehicle (GPV) equatorial transport overpass (uWay) runs along the equator of the Earth and creates a closed ring. Its route crosses three oceans and two continents, on which there are mountain ranges. Such an arrangement makes it possible to unite huge territories into a single transport and infrastructure network; at the same time, it causes many difficulties in implementing this project both on land and on oceanic sections.

The construction of the uWay will certainly be one of the most ambitious projects of mankind on the planet and will raise the Earth's transport industry to a new level, but its main purpose is not only in this. The overpass will become a launch and landing platform for the GPV [1, 2]. The GPV will carry out transport communication between the Earth's surface and the orbital industrial complex, where the entire industry of the future space civilization will be located. Thanks to the presented solution, the Earth's biosphere will be freed from the harmful impact of technological progress.

This is a long journey. Its start will begin with the construction of intermediate supports along the equatorial line. The length of the uWay will amount 40,076 km, hundreds of thousands of supports will be needed for its construction, including high (more than 100 m) and very high (more than 300 m) ones. Therefore, one of the main tasks is to reduce the cost of the design while preserving all operational functions. At the same time, the support must withstand all the loads created by the uWay, gusts of heavy wind, and earthquakes.

The purpose of the study is to analyze the loads that act on the intermediate support of the uWay; to calculate the optimal shape of the support, according to the authors; to consider different versions of the internal power grid under the same operating conditions.

Literature Review

In 1989, an analysis of the possible versions of intermediate support designs of the uWay and their material consumption was carried out [2]. The number of supports up to 100 m high was 10 %.

However, this height is not enough to pass through mountain ranges. The calculation of the optimal trajectory of the GPV rotor in South America and Africa with radii of vertical curvature of 100 km, 1,000 km, and 5,760 km (the radius of the Earth along the equator is 6,378.1 km) showed the need for supports with a height of 300 m and more [3].

It is impossible to work out such a complex structure without relying on existing project designing experience. There are no analogues of the uWay in the world, but as an example, we will analyze the objects that have made a breakthrough in their time.

The first steel bridge was built in 1779 in Shropshire (England) under the direction of A. Derby [4]. Further on, the quality and quantity of metal structures began to develop exponentially.

Thanks to the development of the open-hearth furnace, the 19th century became a time of large-scale use of steel in the erection of bridges. During this period, the following giants were built:

- Forth Bridge (1890): span – 210 m, height in the support zone – 100.6 m;
- Britannia Bridge (1850): total length – 460 m, spans – 140 m.

In addition, many more bridges were installed using ductile iron, which opened a new era of construction, thereby allowing the construction of lightweight, delicate structures leaving behind heavy stone and concrete ones.

The next stage in the development of metal structures is mastering of low-carbon steel smelting and the use of alloying additives. It happened at the beginning of the 20th century, when the previous versions did not meet the requirements of architecture. One example is the "Palace of Soviets" steel, developed in the Soviet Union to implement a grandiose project – the construction of the Palace of Soviets.

At the same time, the production of steel intended for the production of load-bearing ropes and high supports (pylons) of suspension bridges, which have found wide application in the USA, has been developed. In particular, the Golden Gate Bridge was built in San Francisco (1937): its total length is 2,737 m; the height of the pylon is 227 m.

The use of such structures required additional research and led to the identification of specific effects associated with wind vibrations – aeroelastic vibrations of large-span and high structures, as well as the frequency characteristics of wind flows.

Presently, the implementation of high-rise projects is no longer something unusual. Thus, the development of new materials (based on concrete and metal) allows the construction of objects up to 820 m high (currently the tallest building is located in the UAE – the Burj Khalifa Tower (2010)) and higher (a 1,300-m building is under construction in the UAE).

There are already bridges with high supports in world practice. The example, most similar to the designed overpass according to the construction conditions, is the suspension bridge over the valley of the Sidu River in Hubei Province in China. Its length is 1,341 m, the height of the supports relatively to the foundation base is 269 m and 245 m. The bridge was built in a mountainous area and opened for traffic in 2009. However, the highest (343 m) bridge support in the world currently belongs to the Millau Viaduct [5]. The length of this bridge is 2,460 m (2004).

As we can see, since 1989, when the first studies of design versions of intermediate supports took place, progress in the field of construction has not stood still. Each new structure, during the construction of which great difficulties arose, motivated the creation of new technologies. Looking at the number of issues facing specialists designing the uWay, we can say that many unique innovative technical solutions will be presented, some of which are discussed further in this article.

Main Loads on the Intermediate Support

For the correct analysis and calculation of intermediate supports, it is necessary to consider the GPV structure features and operating principle [1, 2]. It consists of an outer shell, on which all equipment and payload are attached, and an internal rotor, the speed of which reaches 12 km/s. When the rotor accelerates, a lifting force is created, which ensures the start of the GPV. In this case, the resulting force of attraction varies from the total weight of all elements to negative values.

Load from the GPV

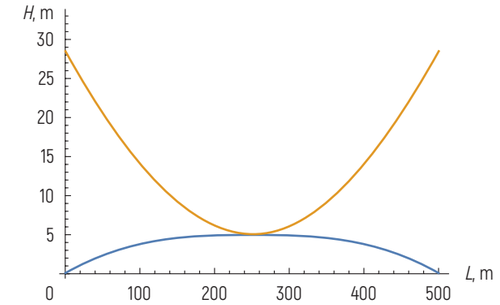
The weight of the GPV can vary from 1,000 kg to 0 kg per running meter and vice versa during takeoff and landing, which is important to take into account when calculating the uWay and its supports.

The GPV also sets a number of requirements related to the functioning of the rotor inside it under all operating modes. After turning on the complex, the rotor movement does not stop. This is due to the fact that additional energy needs to be spent on stopping the rotor after landing, which will have to be restored for the next launch. Accordingly, the shape of the uWay should always correspond to the optimal operating mode of the rotor.

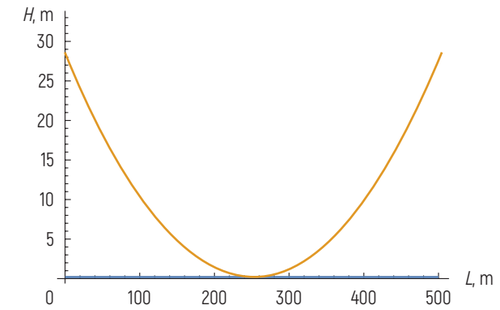
Load from the uWay

The choice of the type of superstructure significantly affects the weight of the overpass, as well as its windage.

The most common bridge structures are beamed span structures with solid and grating walls, as well as arched, cable-stayed, and suspension bridges [6]. Hanging systems can provide the largest amount of span with minimal cost of materials. Consequently, for the calculation of intermediate supports, the authors chose a prestressed string-rail cable-stayed truss (Figure 1) with its own weight of 1,000 kg per running meter. Transportation lines of Unitsky String Transport (uST) will pass along the lower stabilizing belt and a runway for the GPV will be located there.



a)



b)

Figure 1 – Prestressed cable-stayed system:
a – without the GPV; b – with the GPV

With the height of the intermediate supports of 300 m, it is irrational to use small spans of the equatorial overpass. A span of 500 m is accepted for all variants of supports.

The total tension of the upper and lower belts of the cable-stayed truss amounted to 3,700 tons. The height of the pylons is 30 m. Deformation under the GPV weight is 5 m.

Large deformations of the GPV will lead to a malfunction in the operation of linear rotors moving at cosmic velocities. It is necessary to minimize any deviations from the ideal trajectory of movement until the moment of separation from the uWay. There are several ways to solve this problem:

- increase of the rigidity of the uWay while reducing the length of the spans. However, this approach will significantly raise construction costs;
- compensation for the loss of the GPV weight from the lifting force generated by the rotor due to uniform adjustable ballast (for example, filling tanks with water along the entire length of the uWay). For proper operation of the entire system, the rate of change in the lifting force created by the rotor and the addition of ballast should be synchronized;
- use of mechanization (for example, the installation of hydraulic systems to align the GPV along an ideal trajectory). In such an option, synchronization with the operation of the rotor is also necessary, but at the same time the cost increases due to the use of expensive equipment.

The most economical option of the above is lifting force compensation, which will require a minimum amount of mechanization and materials for its implementation. Thanks to modern control systems, it is possible to arrange a synchronous operation.

Wind Load

EN 1991-1-4-2009 "Eurocode 1. Actions on Structures. Part 1–4. General Actions. Wind Actions" was used to determine the wind load [7, 8]. This regulatory documentation sets a limit on the height of the calculated structure of 200 m, but since there are no statistical characteristics of the wind flow at a height of more than 200 m from ground level at the site of the proposed construction, the above limitation is not taken into account in this work.

At the moment, no surveys have been conducted in the area of the construction of the uWay to determine the maximum wind speed. There are scattered observations in different countries, which often do not exceed $V_{b,0} = 30$ m/s.

Seismic Load

The uWay runs through many seismically active zones [9, 10], which imposes design requirements both to the supports and to the execution of their nodes.

Figure 2 shows all cases of earthquakes of different intensity for the period 1976–2005. When designing supports, it is necessary to focus on detailed and the most recent studies of specific regions. Seismic activity can be reviewed on the website volcanodiscovery.com [11].

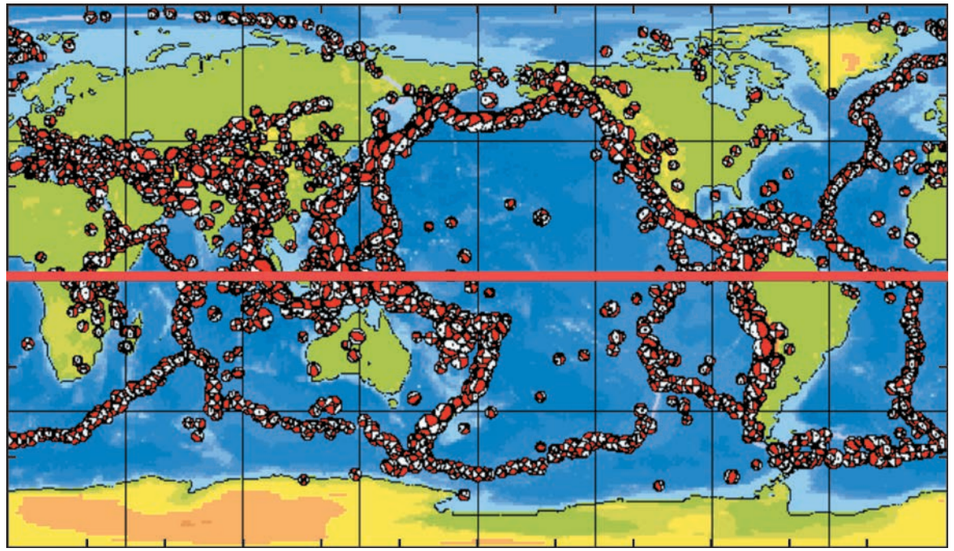


Figure 2 – Earthquake areas for the period 1976–2005 [10]

In this work, the calculation was carried out according to the general rules EN 1998-1-2011 "Eurocode 8. Design of Structures for Earthquake Resistance. Part 1. General Rules, Seismic Actions and Rules for Buildings" [12].

Selected Design Solutions

If the seismic load is not taken into account, the main forces acting on the intermediate support of the uWay are concentrated loads in the vertical and horizontal planes at the top of the support, as well as distributed load in the horizontal direction over the entire height of the support. Depending on the dominant force, the shape of the support may vary. If a concentrated horizontal load prevails (wind pressure on the overpass), the support posts are aligned in a line. With other combinations of loads, the posts become more curved.

A double-intersecting grid is considered optimal for such types of supports [13]. The braces intersect along the central axis of the support (Figure 3) in order to reduce the calculated length. This is the most acceptable shape to ensure high rigidity with minimal use of materials.

The distance between the posts and their shape are selected with regard to the conditions of uniform effort over the entire height of the support.

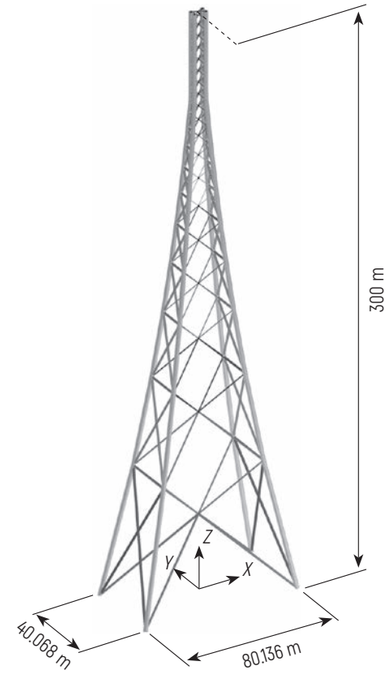


Figure 3 – Variant of the uWay intermediate support

To reduce the length of the braces and the main-posts, it is necessary to add extra links by splitting the pyramidal sections (Figure 4a) into smaller ones (Figure 4b) dividing the calculated length of all elements into two (Figure 4c). As a result, a grid with a single seal was obtained (Figure 4d).

All work on modeling such supports is very time-consuming and it will take too much time in the scale of the entire uWay. To speed up the process, an algorithm has been written that will generate similar grids of any multiplicity, depending on the geometry of the support.

To determine the effectiveness of such a method, a calculation was carried out without a sealing and with single, double, and triple sealing of the grid (Figure 5).

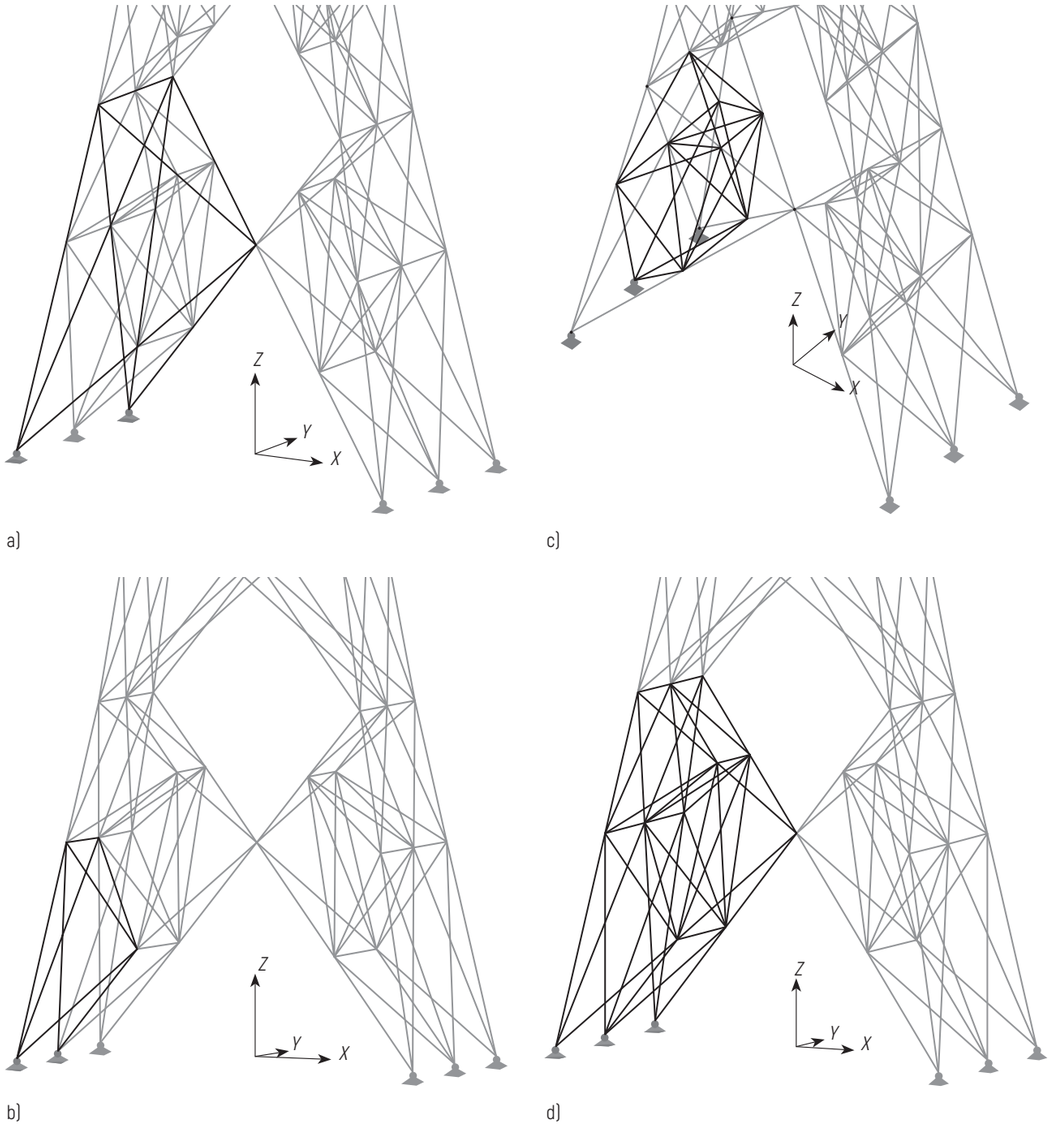


Figure 4 – Sealing of the support grid:
a – section of the support grid; b – splitting into new sections;
c – adding new elements; d – final view of the grid

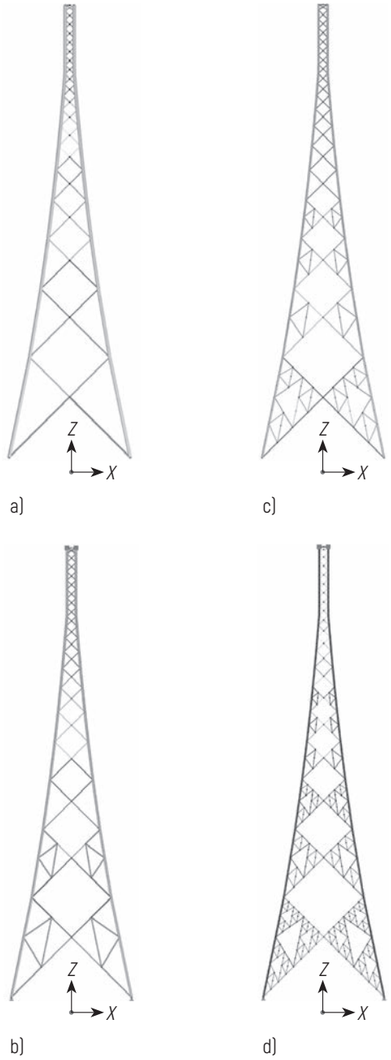


Figure 5 – Support grid sealing:
a – grid without sealing; b – grid with a single sealing;
c – grid with a double sealing; d – grid with a triple sealing

Calculation Results

The calculation showed that the geometry of the support for the loads is selected correctly; practically over the entire height of the support, the compression force *N* in the posts is the same at ULS (Ultimate Limit State) (Figure 6).

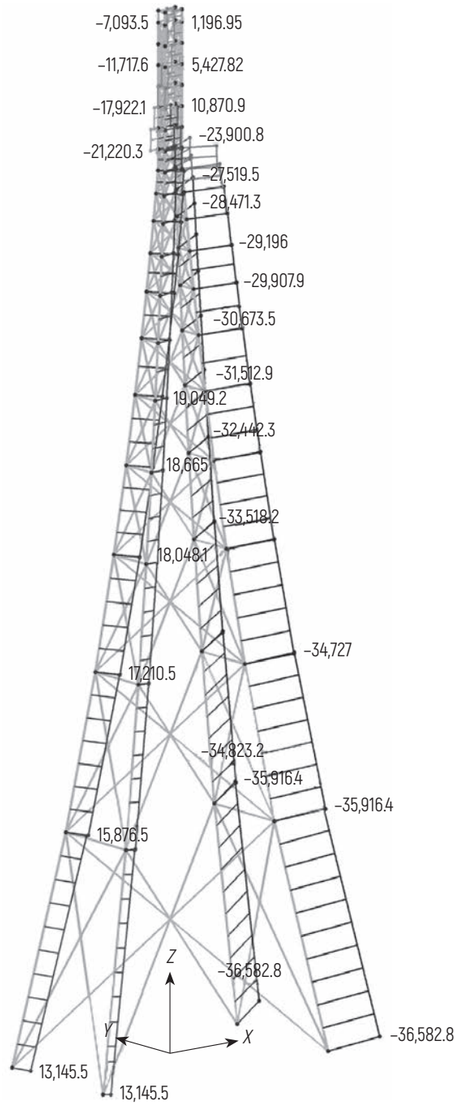


Figure 6 – Epure *N* in the support posts at ULS, kN

The first four types of intrinsic oscillation frequencies are determined (Figure 7). The calculation was carried out taking into account the weight of the uWay and the GPV located on it. None of the types is torsional.

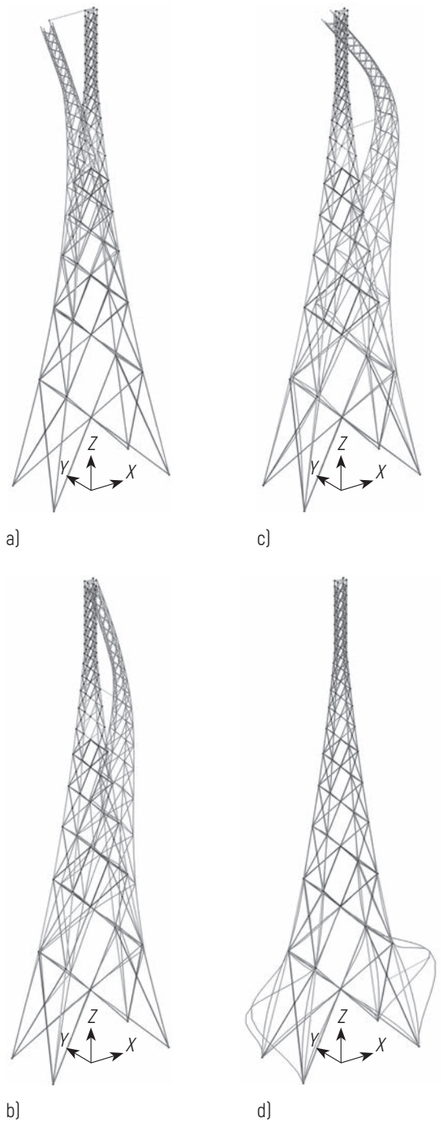


Figure 7 – Types of intrinsic oscillation frequencies:
a – first type – 0.341 Hz; b – second type – 0.644 Hz;
c – third type – 0.934 Hz; d – fourth type – 1.103 Hz

Let's consider each type separately:

- first type oscillates perpendicular to the transport overpass;
- second type performs vibrations along the transport overpass;
- third type is a more complicated version of the first type;
- fourth type shows the vibrations of the lower bracing grid. In order to avoid these vibrations, it is necessary to increase the rigidity of the braces.

The maximum transverse displacements normally occur at the tops of the supports – 1,055 mm (Figure 8).

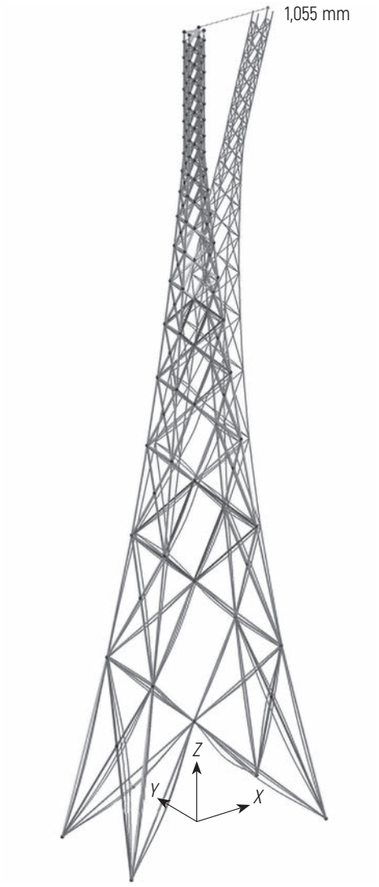


Figure 8 – Maximum deformations of the support without sealing of the grid

When calculating deformations created by seismic loads, the type of the elastic spectrum of reactions is chosen (Figure 9).

The obtained deformations are significantly less than the values detected from the wind load and amounted to 58.1 mm for a support without a grid sealing and 77 mm for a support with a triple sealing (Figure 10).

The above results are presented only for the support without grid sealing. For all other types, the information is provided in the Table.

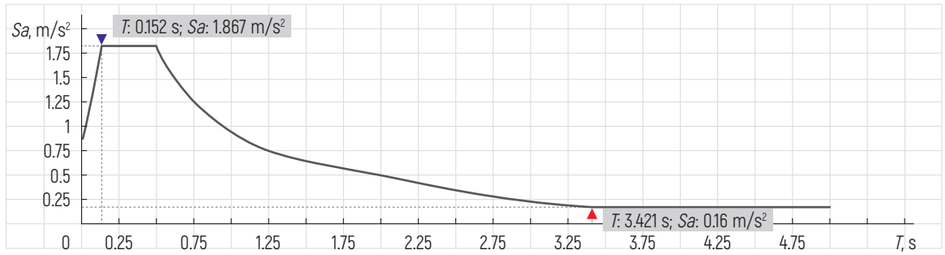


Figure 9 – Type of elastic spectrum of reactions

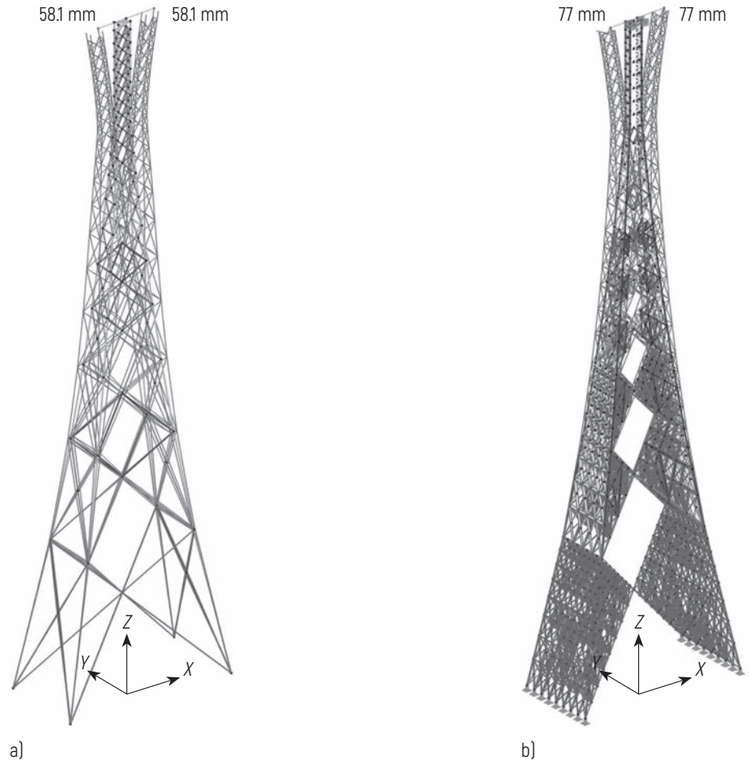


Figure 10 – Maximum deformations of the support from seismic loads:
a – support without grid sealing; b – support with triple grid sealing

Table – Results of comparison of supports with different types of grid

Characteristic \ Support type	Without grid sealing	With single grid sealing	With double grid sealing	With triple grid sealing
Support weight, tons	3,814	3,028	2,542	2,290
Cross-section of main posts, mm	2,134 × 36	1,727 × 30	1,422 × 28	1,219 × 25
Intrinsic frequency without overpass and GPV, Hz	0.596	0.614	0.629	0.68
Intrinsic frequency with overpass and GPV, Hz	0.341	0.296	0.27	0.24
Support deviation at SLS, mm	1,055	1,578	1,993	2,779

Conclusions and Future Work

The calculation of different versions of the internal grid of this type of supports showed that the geometry of the main posts affects the rigidity and deformation of the structure. A reduction in the cross-sectional area leads to a decrease in the total weight of the support, but increases transverse deformations from external loads.

After analyzing the considered issues, it is also possible to draw up the following conclusions:

- before starting project designing, it is necessary to conduct climatic and seismological studies on the route of the uWay;
- construction of the uWay with spans of 500 m according to the type of a prestressed cable-stayed system is possible, however, a number of issues related to deviations from the ideal trajectory of the rotor movement should be resolved;
- objectively, there will exist local deviations of the uWay from the axis of the track, which will create deviations from the ideal rotation plane of the GPV rotors and it will require finding a solution to this problem (e.g., creation of a rail mechanism on each support across the overpass, which will hold the overpass within appropriate tolerances);
- to speed up the process of designing the uWay and its supports, it is reasonable to develop a special software package.

In further work, it is necessary to consider in more detail the design of the uWay, taking into account the peculiarities of the GPV launch and landing.

After a conceptual study of all the GPV elements and the overpass, it is necessary to make the layout of the route trajectory, taking into account all the features and limitations. This will allow the installation of supports on the terrain and perform a refinement of their heights, which means it will be possible to assess the overall material intensity of manufacturing the supports and the complexity of their erection.

In addition, it makes sense to analyze the option of locating the uWay bypassing major mountains.

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UDC 004.942

Protection of the General Planetary Vehicle from Meteoroids and Space Garbage

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Due to the constant increase in the number of spacecraft (SC), the amount of space garbage (SG) in near-Earth space is continuously increasing. Particles of meteoroids and man-made debris moving at high speeds pose a serious threat to flying vehicles staying in near- Earth orbits. Unique in its structure and dimensions, the General Planetary Vehicle (GPV) is planned to be operated in orbit for a long time, which increases the likelihood of its collision with various SG. It is necessary to ensure reliable protection of the GPV shell from SG for its safe functioning. This article contains the analysis of space objects that pose a risk for the GPV in the operational orbit. Typical sizes and velocities of SG particles are shown. Versions of the GPV protective structures are proposed depending on the degree of criticality of the consequences of an encounter with meteoroids. Based on the limiting ballistic equations, the parameters of protection against SG with a size of 2 mm are selected. Numerical simulation of ballistic tests in the LS-DYNA finite element analysis package using the smoothed particle method was carried out to determine the stability of the GPV body in collision with SG particles of 5 mm in size. Johnson – Cook and Cooper – Symonds models were used to describe the response of materials. Verification of models and approaches was carried out by comparing the simulation results with the data presented in open sources on full-scale experiments of piercing a fragment of the tank wall in the Spektr-UV satellite.

Keywords:
General Planetary Vehicle (GPV), high-speed damage, antimeteoroid protection, space garbage (SG), finite element method, numerical simulation.

Introduction

When designing spacecraft (SC), it is necessary to consider their complicated operating conditions and the loads to which the structure will be subjected during operation. Such parameters include great temperature differences, deep vacuum, vibration, cosmic and solar radiation, as well as the consequences of the impact from outer space in the form of high-speed space objects. All of these factors have an impact on the structure for a long time and should be taken into account when designing the body of the General Planetary Vehicle (GPV) [1]. It is important that the GPV shell reliably protects the structure itself, the equipment located inside, cargo, and, above all, passengers. At the same time, the GPV body must have a minimum mass and be technologically advanced in production [2].

Space objects that pose a threat to SC can be divided into two categories: natural meteor bodies (meteoroids) and artificial fragments of the orbital space garbage (SG). Meteoroids are particles of comets and asteroids moving in orbit around the Sun and having an average velocity in near-Earth orbit of about 19 km/s. The density of such celestial bodies ranges from 0.5 g/cm^3 to 2 g/cm^3. SG consists mainly of non-functional parts of SC orbiting the Earth (metal fragments, paint, aluminum oxide, etc.). The speed of movement of such objects, as a rule, is lower than that of meteoroids, and averages 8–9 km/s at an altitude of about 400 km. Typically, the density of SG particles is 2.8 g/cm^3 [3–5].

Determination of Parameters for GPV Body Protection from Space Garbage

Description of Types of GPV Antimeteoroid Protection

To select the parameters for the GPV protection against SG at the design stage, it is proposed to divide the structure of protective screens into three types (according to the criticality of the consequences of hull breakdown):

- the minimum required protection against the most common SG present in the GPV orbit (protection against particles up to 2 mm in size). In this case, damage to the hull is insignificant, and does not affect the functioning of the GPV as a whole;
- protection of systems in which a failure may eventually affect the GPV operation (protection against particles up to 5 mm in size);
- protection of sections of the GPV body. Their breakdown leads to a failure of the basic systems, without which further operation of the GPV is not possible (protection against particles larger than 1 cm).

SG more than 10 cm are tracked from the Earth. Information about such objects is kept in special catalogs, and the trajectory of movement is calculated by programs. The consequences of a collision of large particles with SC body are catastrophic, therefore, active protection (departure to another orbit) is used to exclude collisions.

When creating protective screens, high-strength metals and their alloys, metal composites, porous, fibrous, and other materials are used, to which the following requirements are put forward: minimum density, high viscous-ductile properties, and hardness. The most common in the production of protective screens are aluminum alloys, titanium, and steel. For further investigation of the protective properties of screens, aluminum-alloy sheets will be accepted as the most popular in terms of price/quality ratio, aluminum foam as one of the most energy-intensive materials and steel wire grids with good strength properties at low surface density.

Protection from Space Garbage of 2 mm in Size

The simplest protection against SG is single-layer screens. Their thickness P can be determined with a sufficient degree of accuracy by the ballistic formula [6]:

$$P = 5.24\, d_p^{\frac{19}{18}} HB^{-0.25} \left(\frac{\rho_p}{\rho_w}\right)^{0.5} (V\cos\theta)^{\frac{2}{3}}, \quad (1)$$

where d_p – particle diameter, cm;

HB – Brinell hardness of the shield material;

ρ_p, ρ_w – density of the particle and wall material, respectively, g/cm^3;

V – particle velocity, km/s;

θ – the angle of particle impact with respect to the standard of the shield surface, rad.

Condition of non-penetration of a single monolithic wall [6]:

$$\delta_w \geq 1.8P. \quad (2)$$

When SG particle (average speed of movement – 8 km/s; diameter – 2 mm) moves along the GPV orbit, the thickness δ_w of the screen wall is in accordance with formula (1) and condition (2):

$$\delta_w \geq 1.8 \times 5.24\, d_p^{\frac{19}{18}} HB^{-0.25} \left(\frac{\rho_p}{\rho_w}\right)^{0.5} (V\cos\theta)^{\frac{2}{3}}. \quad (3)$$

As a result of calculations, when the particle interacts with the screen according to the standard, it turns out that the wall thickness should not be less than:

$$\delta_w \geq 1.8 \times 5.24 \times 0.2^{\frac{19}{18}} \times 95^{-0.25} \left(\frac{2.8}{2.7}\right)^{0.5} (8\cos 0)^{\frac{2}{3}} \geq 1.25 \text{ cm}.$$

At the same time, the value of the surface density of the protective screen will be 33.8 kg/m^2.

Despite the simplicity and low cost, currently single-layer screens are practically not used due to their large mass. It is much more efficient to use multilayer shields (Whipple shields) capable of withstanding the impact of relatively large SG particles. The first screen (bumper) is made thin; its main purpose is to break a high-speed SG particle into many fragments and disperse them as much as possible behind the bumper in order to distribute the load on the next wall over a larger area.

The thickness t_b of the bumper can be determined by the formula [6]:

$$t_b = c_b d_p \times \frac{\rho_p}{\rho_b}, \quad (4)$$

where $c_b = 0.25$ at $15 < S/d_p < 30$ or $c_b = 0.2$ at $S/d_p \geq 30$;

S – distance between the bumper and the main wall, cm.

Thus, at $S = 4$ cm, the thickness of the bumper can be accepted as:

$$t_b = 0.25 \times 0.2 \times \frac{2.8}{2.7} = 0.052 \text{ cm}.$$

Thickness t_w of the main wall [6]:

$$t_w = c_w d_p^{0.5} (\rho_p \times \rho_w)^{\frac{1}{6}} m_p^{\frac{1}{3}} \left(V \times \frac{\cos\theta}{S^{0.5}}\right) \left(\frac{70}{\sigma_y}\right)^{0.5}, \quad (5)$$

where c_w – coefficient equal to 0.16 cm^{2}s/(g$^{2/3}$km);

m_p – mass of SG particle. For an aluminum sphere with a diameter of 0.2 cm, the particle mass will be 0.01173 g;

σ_y – material plasticity limit, for Al 6061-T6 it is equal to 40 ksi.

At a distance of $S = 4$ cm, the thickness of the main wall will have the following value:

$$t_w = 0.16 \times 0.2^{0.5} (2.8 \times 2.7)^{\frac{1}{6}} \times 0.01173^{\frac{1}{3}} \left(8 \times \frac{\cos 0}{4^{0.5}}\right) \left(\frac{70}{40}\right)^{0.5} = 0.17 \text{ cm}.$$

Thus, to protect the GPV body from SG with a size of 2 mm, two screens with a thickness of 0.5 mm and 1.7 mm, spaced 40 mm apart, can be used. At the same time, the total thickness of the material of the two walls will be 2.2 mm, the surface density will decrease by more than five times compared to a single-layer screen and will be equal to 6 kg/m^2.

Protection from Space Garbage of 5 mm in Size

To protect the GPV body from particles of 5 mm in size, it is necessary to increase the thickness of the walls or their number, which will lead to a significant increase in the mass of the screen, and, respectively, to a decrease in the GPV payload. In addition, the installation of several screens expands the body and complicates the structure by using fasteners. Protective screens made in the form of sandwich panels, i.e., panels consisting of layers of various materials, are more efficient. As a filler between the bumper and the main sheets, honeycomb panels made of aluminum or carbon fiber, corrugated sheets, grids with different wire thicknesses and different lumen, barriers made of reinforced plastic, metal foam or layers of woven materials (Kevlar, Armos, Nextel, etc.) can be used. Existing ballistic equations are not able to cover such a variety of options for protective screens, so such structures need to be tested in laboratory conditions. The experiments are carried out by firing the studied panels from light-gas cannons, allowing the striker to accelerate to a speed of 8 km/s. Conducting numerous tests in a large range of sizes and speeds of strikers, materials, thicknesses, and their alternation options requires huge material and time resources. Accordingly, the calculation of the structure of the protective screen from SG with a size of 5 mm is carried out using numerical simulation. Preliminary, it is necessary to verify the models based on the results of full-scale experiments presented in open sources.

Simulation of Space Garbage Collision with GPV Protection

Description of the Solver and Simulation Method

The ANSYS LS-DYNA software package designed for nonlinear dynamic calculations is used to calculate the penetration capacity of protective screens. The simulation was performed by an explicit method using a Lagrangian solver as the most accurate and efficient. Since large deformations occur during collisions with space debris and destruction occurs, in which fragmentation of SG into small particles is observed, the grid-free SPH (Smooth Partial Hydrodynamics) method is preferable for modeling. It allows calculating with arbitrary deformations while preserving the advantages of the Lagrangian approach [7, 8].

In high-speed collision problems, the material model must contain elastic-plastic deformation and destruction. To describe the behavior of materials at high deformation rates, two most commonly used models are selected for these tasks: Johnson – Cook and Cooper – Symonds.

The Johnson – Cook model takes into account the deformation hardening and the dependence of stress on the deformation rate and temperature. The plasticity limit σ_y is determined by the formula:

$$\sigma_y = (A + B\varepsilon_p^n)\left(1 + c\ln\frac{\dot{\varepsilon}_p^n}{\dot{\varepsilon}_0}\right)\left(1 - \left(\frac{T - T_r}{T_m - T_r}\right)^m\right), \quad (6)$$

where A, B, c, n, m, ε_0 – model parameters;

ε_p – effective plastic deformation;

T – current temperature;

T_r – room temperature;

T_m – melting temperature.

The Cooper – Symonds hardening model makes it possible to show plastic deformation with breakage and takes into account the effect of the deformation rate on the plasticity limit value [9, 10]:

$$\sigma_y = \sigma_0\left(1 + \left(\frac{\dot{\varepsilon}}{C}\right)^{\frac{1}{P}}\right), \quad (7)$$

where σ_0 – static plasticity limit;

$\dot{\varepsilon}$ – deformation rate;

C, P – material constants.

To describe the relationship between the pressure and the volume of the material in the process of shock compression, the Mie – Gruneisen equation of state is used [11]:

$$p = \frac{\rho_0 C_0^2 \mu\left(1 + \left(1 - \frac{\gamma_0}{2}\right)\mu - \frac{a}{2}\mu^2\right)}{\left(1 - (S_1 - 1)\mu - S_2\frac{\mu^2}{\mu + 1} - S_3\frac{\mu^3}{(\mu + 1)^2}\right)^2} + (\gamma_0 + a\mu)E, \quad (8)$$

where ρ_0 – initial density;

C_0 – volumetric speed of sound;

μ – nominal volumetric compression strain, determined as $\mu = \rho_0/\rho - 1$;

ρ – density;

γ_0 – Gruneisen coefficient;

a – volume correction factor;

S_i – slope coefficient of the shock adiabat;

E – internal energy.

Model Verification

A necessary condition for simulating a high-speed impact, the consequence of which is destruction, is the presence of a verified model of the behavior of materials under specified loading parameters. To verify the mathematical models used, numerical simulation of the penetration of a fragment of the Spektr-UV satellite tank by an aluminum sphere with a diameter of 2 mm was performed (Figure 1).

The simulation results are shown in Figure 2.

During the simulation, the front wall collapsed. Its fragments and debris of the striker spread over the area of the main wall (Figure 2), causing deformation, but no destruction occurred. The simulation results are in good agreement with the experimental data presented in the sources [10, 12], which indicates the possibility of using the selected parameters of the material models.

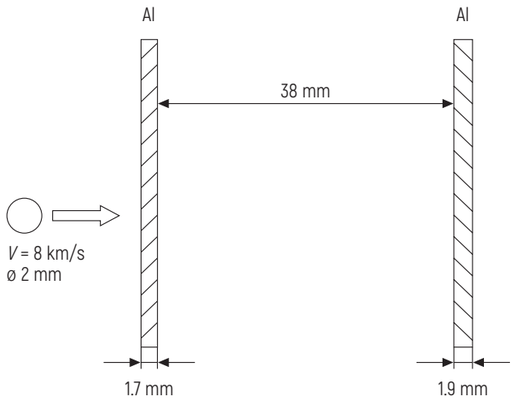

Figure 1 – Diagram of a computational experiment for breaking through a tank fragment

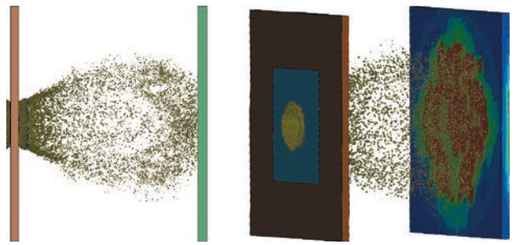

Figure 2 – Simulation of a hit of a sphere with 2 mm diameter on the tank wall

Simulation of Protection Against Space Garbage with a Size of 2 mm

According to formulas (4) and (5), the thickness of the bumper (0.5 mm) and the main wall of the GPV body (1.7 mm) are determined. The initial velocity of SG particle is 8 km/s. The simulation is similar to the scheme presented above.

The results of simulating the breakdown of the protection with two walls are shown in Figure 3.

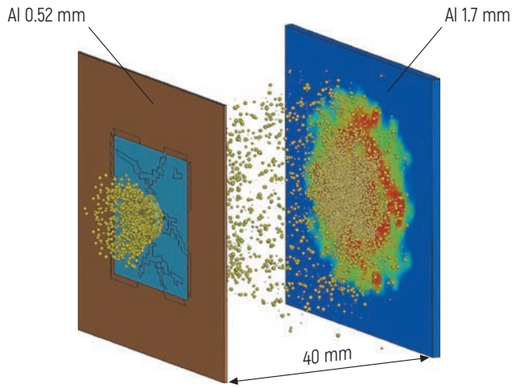

Figure 3 – Simulation of protection against SG with a size of 2 mm

As a result of collision with space debris, the bumper is broken through, and the main wall remains intact, which corresponds to the results obtained by analytical formulas.

Simulation of Protection Against Space Garbage with a Size of 5 mm

To protect the GPV body from SG with a size of 5 mm, in addition to the two screens of the selected sizes, it is necessary to additionally introduce a material with high energy absorption, for example, aluminum foam.

To model aluminum foam, the following material model was used – type 63 *MAT_CRUSHABLE_FOAM of LS-DYNA package [13–15].

To verify the model of this material, a simulation of the full-scale experiment WSTF04-38187 [16] was performed: an aluminum striker shaped like a sphere with a diameter of 4 mm with an initial velocity of 6.79 km/s collided with a screen that was made in the form of a sandwich panel consisting of two sheets of aluminum with a thickness of 0.254 mm and aluminum foam with a porosity of 40 ppi and a thickness of 50.8 mm, located between aluminum sheets (Figure 4).

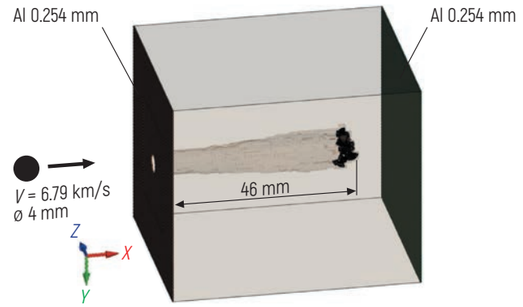

Figure 4 – Breakdown of aluminum foam panel

During the numerical experiment, the penetration depth of the aluminum sphere into the aluminum foam was determined – 46 mm (Figure 4). The simulation result is in good agreement with the data of the full-scale experiment, which indicates the adequacy of the accepted parameters of the material model.

To simulate protection from SG with a size of 5 mm, we take the thickness of 1 mm for the bumper and 2 mm for the main wall (Figure 5). A 60-mm thick aluminum foam panel is installed between them (the panel thickness will be adjusted based on the results of the simulation). To reduce the impact speed and initial fragmentation of the striker, two rows of steel grid made of 20X13 material are installed in front of the screen (wire thickness – 0.9 mm; cell clearance – 1 mm) [17].

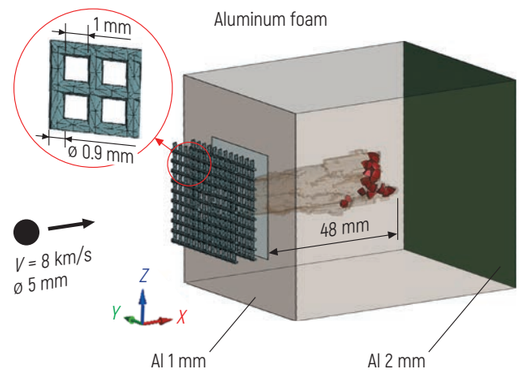

Figure 5 – Breakdown of aluminum foam panel (with two rows of grid)

As it can be seen from Figure 5, the destruction of the grid and bumper occurs. The fragmented parts of the sphere penetrate into the aluminum foam to a depth of 48 mm. The main wall remains intact.

The simulation results showed that it is permissible to reduce the thickness of the aluminum foam panel to 50 mm. The adopted design of the protective screen can be used to protect the GPV body against SG with a size of up to 5 mm.

Protection Against Space Garbage with a Size Larger than 10 mm

Protective screens against SG with a size of more than 10 mm are made in the form of sandwich panels consisting of three or more aluminum sheets, aluminum foam and several dozen layers of woven materials (Kevlar, Nextel). The thickness of these screens can reach from one to several dozens of centimeters, which is due to the size of SG. The implementation of numerical modeling of such structures is a complex and time-consuming process.

The development of this protection is proposed to be carried out at later stages of project designing, when the GPV structural and layout scheme is created and analyzed and the need for such protection is specified.

Conclusion

The purpose of this article was to establish the parameters of antimeteoroid protection of the GPV body from SG. In order to obtain the required information, the main characteristics of SG particles in the GPV operational orbit are systematized: the average velocity of 8 km/s and the density of 2.8 g/cm^3 of SG particles are determined and used in further calculations. Depending on the degree of criticality of the consequences of a collision with SG, the design of antimeteoroid protection is divided into three types: protection against SG of 2 mm, 5 mm, 10 mm and more. With the help of empirical limiting ballistic equations, the thicknesses of aluminum walls capable of protecting GPV from SG up to 2 mm in size are proposed – 0.52 mm and 1.7 mm. Aluminum foam with a porosity of 40 ppi as the main energy-absorbing material is optimal for protecting the GPV body from SG with a size of up to 5 mm, and a screen consisting of two rows of stainless-steel grid is used as the first barrier. The efficiency of the selected SG protection designs was confirmed by modeling ballistic tests in the LS-DYNA package by the smoothed particle method using material models that take into account stress changes depending on the deformation rate, namely Johnson – Cook and Cooper – Symonds models.

To check the adequacy of the considered models of materials and modeling methods, the outcome of modeling were verified with the results of full-scale experiments (in the process of breaking through the tank wall of the Spektr-UV satellite). The data obtained are consistent with each other and allow to conclude that the selected approaches can be used to simulate high-speed breakdown of structures of antimeteoroid protection.

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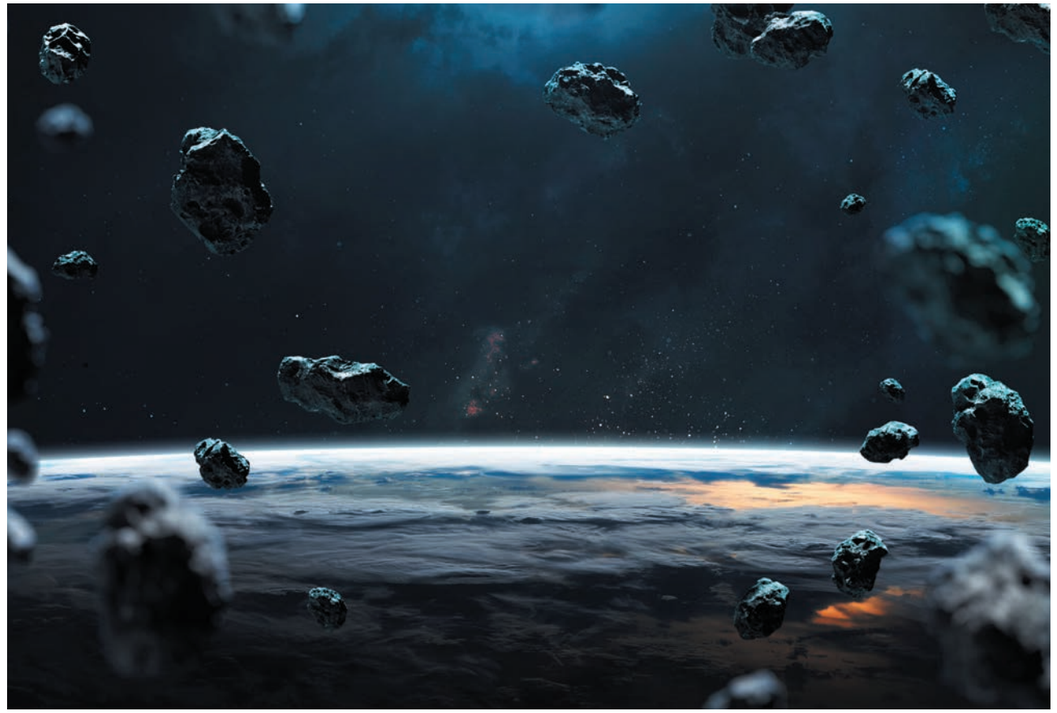

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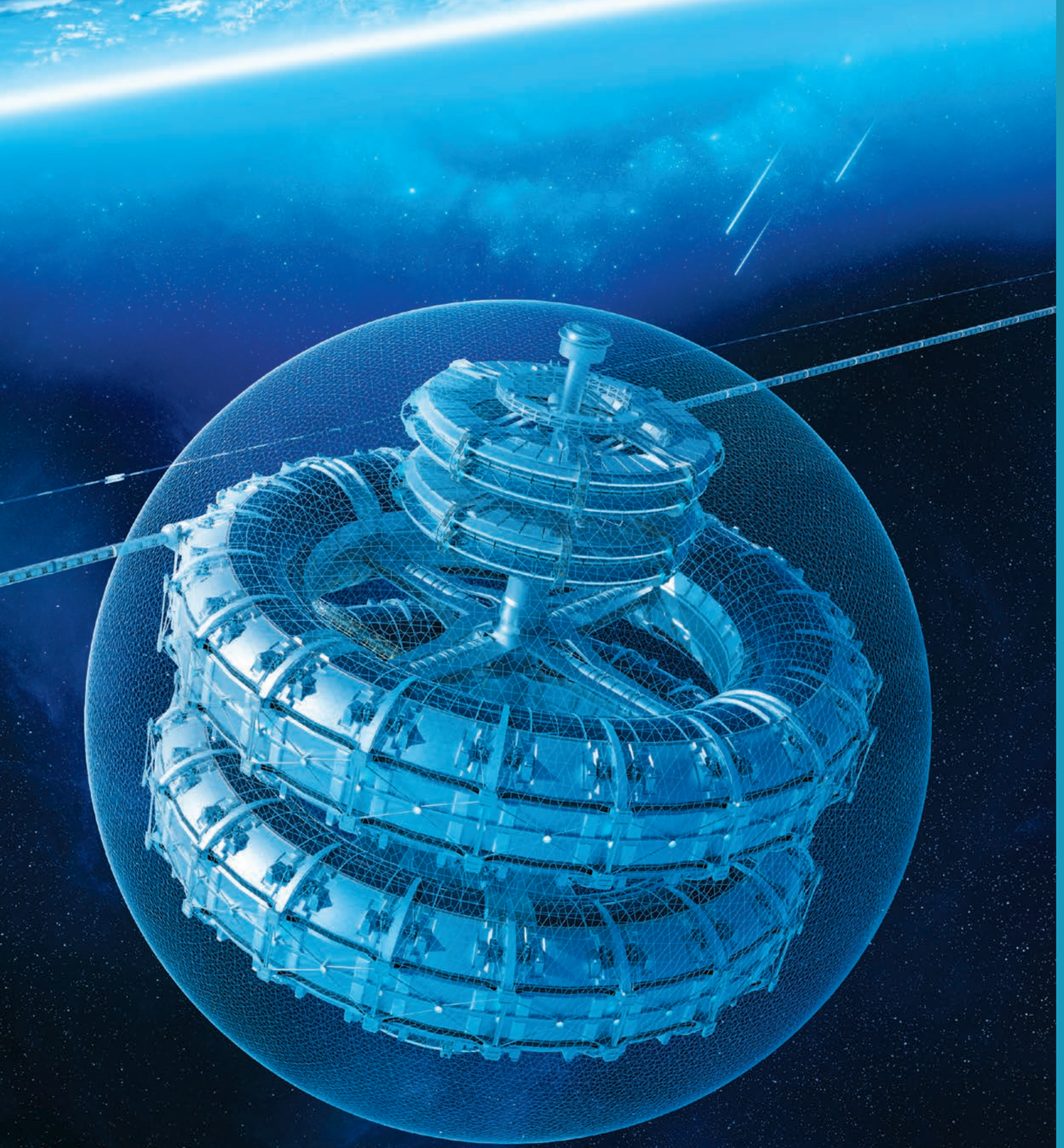

UDC 004.942

Meteorite Protection of Near Space Infrastructure on the Example of EcoCosmoHouse

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Long-term presence of objects in Earth orbit causes their inevitable damaging by small and large meteoroids and the garbage that has been accumulated there for the entire human activity. Taking into account the space velocities appropriate for such orbital elements, a collision with them causes damage that can be critical or even fatal for other objects in orbit. The article reviews two main protection systems for on-orbit objects on the example of EcoCosmoHouse (ECH) which are the active and the passive systems. The active system generates a high-power electrostatic field to prevent such incidents. The passive system is a grid and a multilayer shell that absorb and dissipate the impact energy.

Keywords:
passive protection system, space garbage, meteoroid, cylindrical shell, EcoCosmoHouse (ECH).

Introduction

Any activity under inappropriate conditions in terms of human habitation (in deep ocean, in outer space, on other planets' surface) requires a shelter designed for the human to live and work in comfort. The protective shell is designed depending on the conditions of ambient aggressive environment.

In space such parameters include the absence of a breathable atmosphere, zero gravity, cosmic radiation, and objects with high relative speed. Space activities of mankind have led to the appearance of a huge amount of garbage travelling along the near-Earth orbit with first cosmic velocity. There are fragments of destroyed satellites, parts of rocket shells, tools, etc. among the non-functioning remnants. All known objects can be tracked in real time in the public domain [1].

Figure 1 clearly illustrates a geostationary orbit and a concentration of objects in transfer orbits. Figure 2 shows a great number of bodies on the low-Earth orbits.

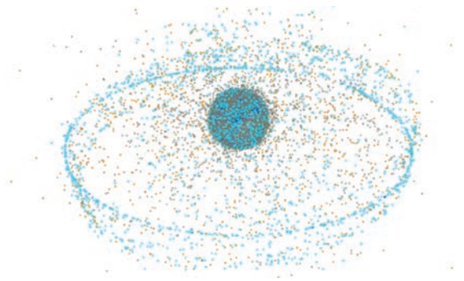

Figure 1 – General view of the near-Earth space with known on-orbit objects (as of April 10, 2021) [1]

Figure 2 – Objects on the low near-Earth space (as of April 10, 2021) [1]

Since EcoCosmoHouse (ECH) as part of the Industrial Space Necklace "Orbit" (ISN "Orbit") [2] operates in low-Earth orbit, an analysis of objects located on it has been carried out, among other things.

Today the number of satellites and the amount of space garbage in low-Earth orbits is on the brink of Kessler Syndrome [3], which means that any accident in orbit can lead to fatal consequences in the form of uncontrolled growth of debris and cause the destruction of most of the artificial Earth satellites in use.

Consider the collision of the Kosmos-2251 and Iridium 33 satellites as an example of such hazardous outcome [4]. The incident happened on February 10, 2009 at an altitude of 805 km at a relative speed of 11.5 km/s. They managed to catalogue over 600 pieces of massive debris that remained on the previous orbits and around 1,800 small fragments scattered on every trajectory. See Figure 3 for the arrangement of the debris after the first revolution around the planet.

Nine years later the travel trajectory of the debris has changed (Figure 4).

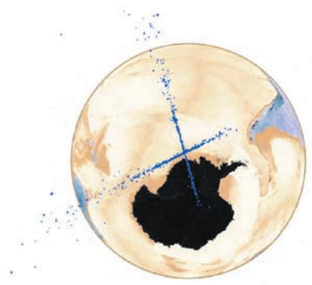

Figure 3 – The layout of the debris formed after the collision of Kosmos-2251 and Iridium 33 (after 50 min) [5]

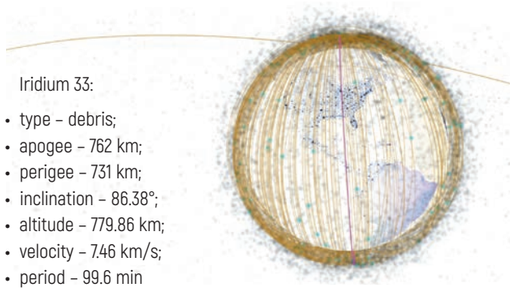

Figure 4 – Trajectory diagram of Iridium 33 debris (nine years after the accident) [1]

The debris produced by this clash alone pose a threat to both near-Earth space and the Earth itself for they occupy the orbits with obsolete spacecrafts produced in the USSR with nuclear microreactors on board [6]. The aftermath endangers the International Space Station as well; in 2012 it had to undertake a maneuver to escape from the collision with Iridium 33 debris [7].

Currently, there are no effective techniques to control space garbage. To rescue on-orbit spacecrafts, it is necessary to make regular escape maneuvers to avoid all sorts of man-made or natural objects. The proposed developments turn out to be either ineffective or aggravate the situation even more [8]. Thus, 13 tests of anti-satellite weapon alone have caused 10 % of all trackable debris on orbit [8].

This research considers the capability to design the active protection system (APS) based on the electrostatic weapon technology [9] which would destroy or de-orbit the debris through the directed electric discharge factor.

Apart from the APS, the structures of the General Planetary Vehicle (GPV) [2], as well as residential and industrial modules, are protected with multi-layered armor to exclude the penetration of foreign bodies through the ECH shell.

Main Principles of the Active Protection System

The APS is an electrostatic field generator, during the passage of which negatively charged fragments of space debris create resonant vibrations in it. High difference in the potentials from the generator to the object initiates a corona discharge. To generate a particle field and ensure the possibility of a discharge, they assume partial vaporization of the conductor and the generation of any other artificial field of ionized particles inside the electrostatic field.

Such protective system is provided for the particles weighing less than 1 kg as the most common types of debris on the low-Earth orbits.

The general operating principle of the system in terms of the exposure to particles is outlined in the calculation below. Only the basic formulas and calculation parameters are given.

Input data:

M = 1 kg (body weight);

V = 10,000 m/s (body velocity);

R_{st} = 250 m (radius of the station – the ECH cylindrical shell).

The kinetic energy is calculated by formula (1):

$$E_k = 0.5\,MV^2. \quad (1)$$

The distance for the deviation of the body towards the required trajectory depending on the applied energy is calculated by formula (2):

$$R(E_{ot}) = \frac{\sqrt{R_{st}\left(E_k^2 + E_{ot}^2\right)}}{E_{ot}} - R_{st}, \quad (2)$$

where E_k is the kinetic energy of the object, J;

E_{ot} is the yield of energy applied to the object to deviate, J.

The graph of the function takes the following form (Figure 5).

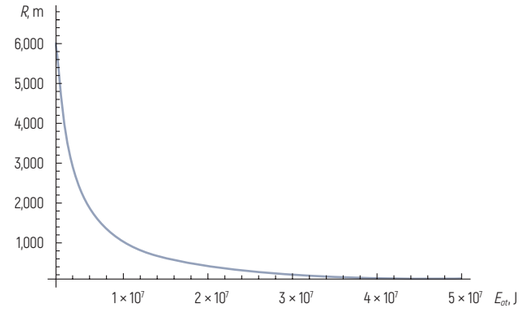

Figure 5 – Energy yield vs distance diagram

Based on the diagram, one could speak of the energy yield required for the deviation of objects weighing less than 1 kg. In terms of energy consumption, the optimum deviation is that of the objects at maximum distance, but even in the relative vicinity of the station it is quite feasible.

Larger threats should be dealt with by the protective shell of ECH that comprises additional elements considered below.

Input Data

The ECH shell is a multi-layered structure. The first protective layer is the mesh made of titanium wire. The properties of the material are specified in the ANSYS software suite and are given in Table 1.

Table 1 – Properties of mesh titanium alloy [10, 11]

Parameter name	Parameter value
Density, kg/mm^3	4.51×10^{-6}
Specific thermal capacity at constant pressure, mJ/(kg·°C)	5×10^5
Parameters upon impact	
Gruneisen parameter	1.23
Parameter C_1, mm/s	5.02×10^6
Parameter S_1	1.536
Squared parameter S_2, s/mm	0
Steinberg – Guinan strength	
Initial yield strength, MPa	850
Maximum yield strength, MPa	1,450
Strain-hardening constant B	210
Strain-hardening exponent n	0.1
Derivative dG/dP $G'(P)$	0.4991
Derivative dG/dT $G'(T)$, MPa/°C	–26.99
Derivative dY/dP $Y'(P)$	0.009775
Melting point, °C	1,986.9
Shear modulus, MPa	43,400

The size of a mesh cell after optimization is 250 × 250 mm, which allows blocking of the major threats to the station. The diameter of the mesh bars is 5 mm. The dimensions of the mesh are taken from the condition of deterring small-sized flat elements based on the analysis of the objects outlined in the interactive catalogue [1].

The mesh acts as the primary deterring layer capable to affect the threat objects, i.e., slow them down by reducing the energy or inflict partial damage. These actions are described in more detail below.

As the second (main) protective layer for the primary calculation, we consider the 100-mm thick steel shell required to dissipate the main energy coming from the threat objects. The properties of the material are given in Table 2. The destruction process is simulated through the complete Jonson – Cook model.

The steel shell is followed by a multimeter layer of special-purpose "space" potting soil (fertile soil for plants) [12]. The soil properties are given in Table 3.

Table 2 – Properties of shell steel [10, 11]

Parameter name	Parameter value
Density, kg/mm^3	7.83×10^{-6}
Specific thermal capacity at constant pressure, mJ/(kg·°C)	4.77×10^5
Bulk modulus, MPa	1.59×10^5
Jonson – Cook strength	
Initial yield strength, MPa	690
Strain-hardening constant, MPa	510
Strain-hardening exponent	0.26
Strain rate constant	0.014
Thermal softening constant	1.03
Melting point, °C	1,519.9
Reference strain rate, s^{-1}	1
Shear modulus, MPa	81,800

Table 3 – Properties of the filler soil [13]

Parameter name	Parameter value
Density, kg/mm^3	0.4×10^{-6}
Isotropic properties of the soil (based on the bulk and shear moduli)	
Strain modulus, kPa	274,220
Poisson's ratio	0.26134
Bulk modulus of elasticity, kPa	191,500
Shear modulus, kPa	109,640
"Surface" of soil destruction	
Initial angle of internal friction, °	31
Initial cohesion, MPa	0.00038
Dilatancy angle, °	31
Reduced angle of internal friction, °	31
Reduced cohesion, MPa	0.00019

The soil is considered by the meshless SPH technique to enable the total behavioral evaluation of a low-strength loose element.

Soil melting in case of excessive energy is neglected in the calculation. The thickness of the soil layer is 10 m. The inside of the soil layer contains two perforated plates (Figure 6). The openings are 500 mm in diameter and 1,000 mm in vertical and horizontal spread.

The first and the second plates are located 5.2 m and 7.6 m from the inner surface of the shell, respectively. These plates are required to interfere with the impact wave initiated by the collisions of threat objects with station wall.

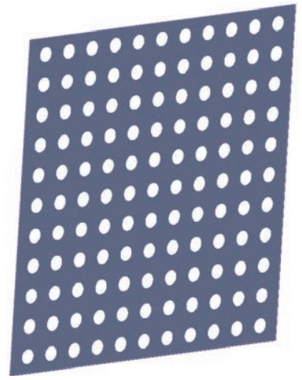

Figure 6 – Fragment of the perforated mesh

The thickness and material of interference sheets are not significant as they are clamped by the soil on both sides. To simulate the process, 5-mm thick aluminum sheets are used.

The average relative velocity of the impact on the station by the object is 15.32 km/s (the velocity of stable bodies on the low-Earth orbit of 400-km altitude is approximately 7.66 km/s; the calculation takes the sum of velocities of two objects that can collide at this altitude). Such relative velocity is approximately three times as high as the sound velocity in metal and almost 10 times [14] as high as the sound propagation velocity in one of the possible forms of solid carbon. Accordingly, the use of other alloys in the analytical model brings changes at the mathematical error bound. The threshold sound velocity in a solid matter is possible in diamond (12–18.3 km/s [14]), although it is economically unviable to implement the ECH shell of it.

In this case, the sound velocity in the material acts as the key parameter. In a solid matter it determines the strain rate of the body. If the strain rate is less than the impact rate of two bodies, the excessive strength (if the shell were made of solid carbon) is not of critical importance. Having no time to absorb the impact through the thickness of the material equivalent to the impacted body in elasticity modulus, the object breaks it through while maintaining the greater fraction of the kinetic energy (Figure 7).

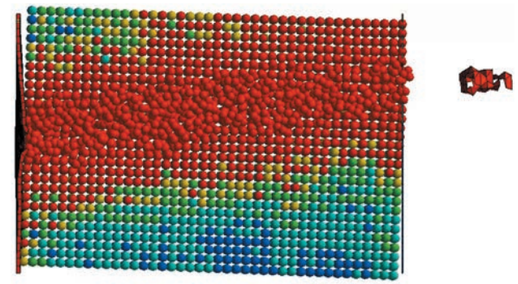

Figure 7 – Penetration by the object of the thin shell and its exit from the structure to the habitable area of ECH

Figure 7 demonstrates that after the threat object has passed through the soil it was strained and partially destroyed. However, it preserved a part of the energy, thus remaining a grave threat to the inner space of the station. The shell itself and the following layer of "space" potting soil experienced minimum changes except for the through-hole left by the threat object.

As discussed above, shell thickness taken as the reference will become the template value for further research and comparisons until new materials are available that are capable to reduce the thickness of the elements.

Figure 8 depicts the diagram of protective layers in the structure of the station. The ECH shell structure is illustrated in Figure 9.

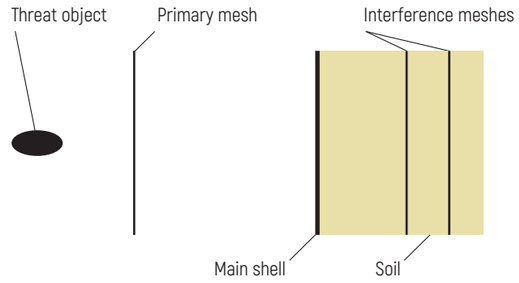

Figure 8 – Diagram of the ECH protective layers

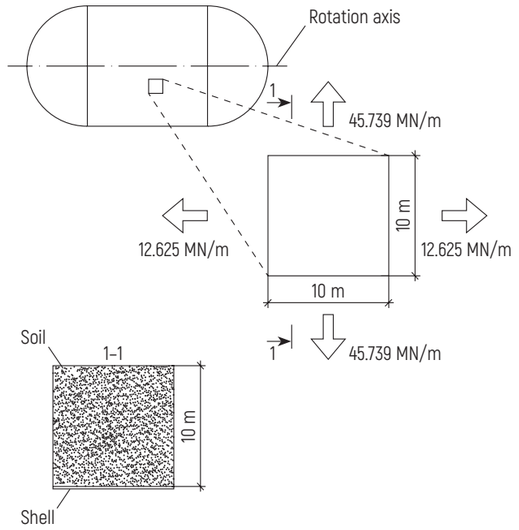

Figure 9 – ECH shell diagram adopted for calculation

We consider three variants of main threat objects:

- 10-kg metal beam;
- 100-kg extended metal beam;
- 900-kg stone meteoroid with ferrite insertions.

Separately, a stone meteorite with ferrite inclusions weighing 150 kg is taken into account for calculating the mesh.

Such selection of objects was made based on the statistical analysis of the data outlined in the catalogue of on-orbit objects [1].

A 900-kg stone-ferrite meteoroid was taken as the largest object; its trajectory is probable to cross that of ECH. Heavier bodies are extremely rare and require to develop measures that are fundamentally different from those studied in this article.

A small meteoroid (150 kg) is studied as a representative object that the mesh can destroy (based on preliminary calculations and research).

Calculation Results for Objects – Mesh Collisions

Let us analyze the interaction pattern of the objects upon impact by the example of a small stone meteoroid with ferrite insertions penetrating through the mesh. The object weight is 150 kg. The overall dimensions are 170 × 570 × × 520 mm.

When hitting the mesh, the object is completely split by the bars (Figures 10, 11).

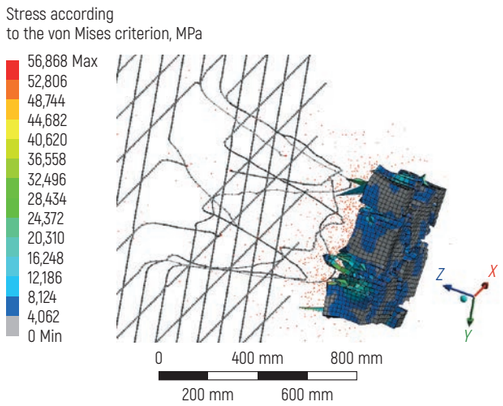

Figure 10 – Pattern of stone object destruction upon hitting the mesh (side view)

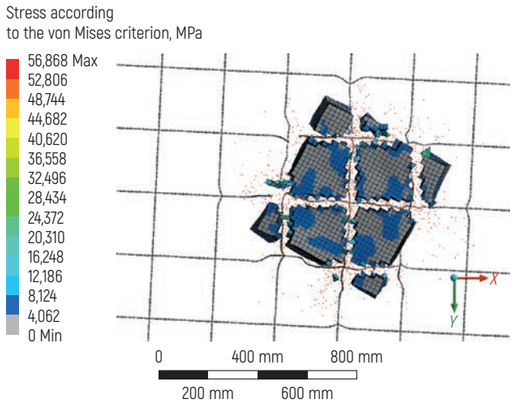

Figure 11 – Pattern of stone object destruction upon hitting the mesh (front view)

The figures show that the mesh is destroyed only partially while the object is completely split into parts. Besides, smaller fragments start changing the trajectory due to insertions in the stone block. Such behavior pattern is explained by the rate of deformation of the element and the material it is made of. A small object does not have time to exert sufficient impact on the mesh and tear it, because it is completely cut through by it. The mesh is strained almost immediately and the fractures are due to edge effects and insertions of metal components into meteoroid composition.

Figure 12 shows the energy lost by the object.

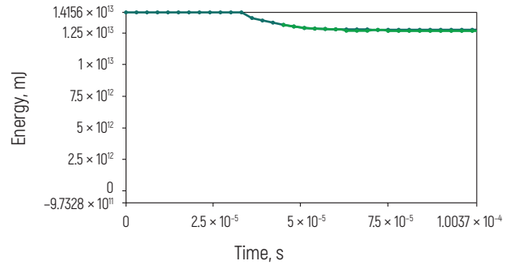

Figure 12 – Graph of kinetic energy drop (in time) for a mesh-hitting object

The total input energy of the system is 1.4156×10^{13} mJ; the output energy (for all objects) is 1.27×10^{13} mJ. The energy drop is 11.5 %. Considering a complete splitting of a large object into small ones, the mesh proved to be quite effective against such threats.

When impacted by more massive meteoroids (900 kg or more), the effectiveness of the mesh is drastically decreased.

A prolate (perpendicular to the mesh plane) object can rip the mesh without serious trouble (Figures 13, 14). Specific shape of the object allows the mesh to rip only the part of it that managed to break through before straining. Then, the damaged mesh is inevitably split and the partially destroyed object moves ahead.

The energy drop is also not critical relative to the total energy of the object and is 2.5 %. Before the collision point it was 9.7563×10^{13} mJ and 9.521×10^{13} mJ after the interaction ended and the system stabilized. The energy change graph is given in Figure 15.

Meanwhile, the mesh can cut sharp protruding corners and small fragments of a large object that entail destructive consequences upon impact to the main protection of the station – the steel shell and the soil.

The mesh is primarily designed to rip high-energy large objects into minor fragments posing no significant threat to the station. In case of prolate metal objects traveling in perpendicular to the mesh surface, it does not constitute a critical obstacle, therefor it is ripped off at the collision points before being strained. However, the mesh guarantees great protection in the event of natural hazards in the form of meteoroids.

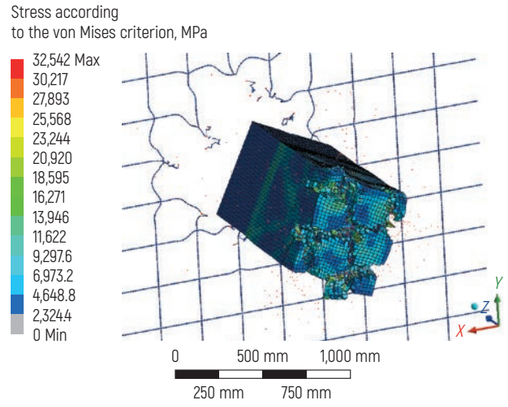

Figure 13 – Mesh destruction diagram upon impact of a large object (view from the impact surface)

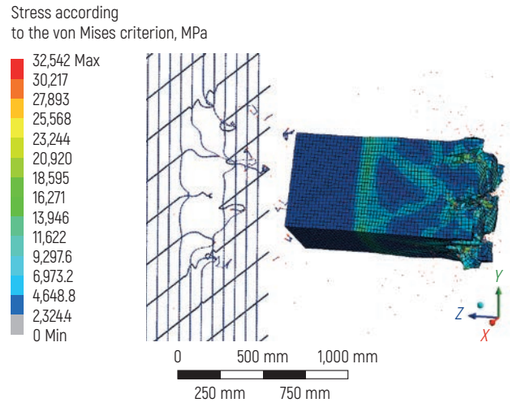

Figure 14 – Mesh destruction diagram upon impact of a large object (side view)

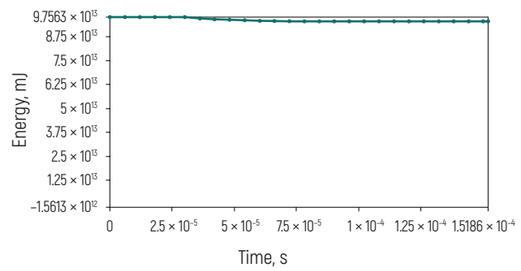

Figure 15 – Graph of kinetic energy drop (for a large object)

Calculation Results for Objects – Main Shell Collisions

First, let us consider the impact of a 900-kg stone-ferrite meteoroid that penetrated through the first level mesh. The analytical model is shown in Figure 16.

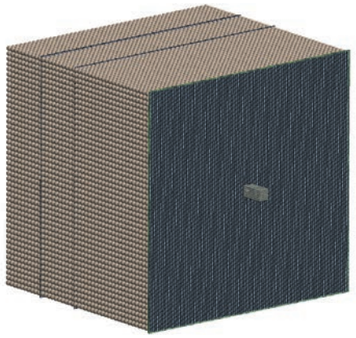

Figure 16 – Analytical model of the ECH main shell upon impact of a large meteoroid

The meteoroid and the soil are implemented through SHP technique; they represent the sets of interconnected particles with different properties (the required parameters are given above).

When a meteoroid first hits the shell structure, a hole is inevitably created (Figure 17).

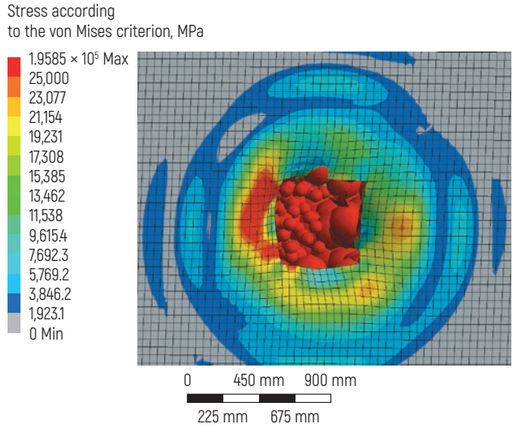

Figure 17 – The nature of the hole appearing in the station shell

Excessive energy makes it impossible to stop the object with the shell regardless of its material. This is evident from the nature of the hole that has a near-perfect smooth cut edge.

After hitting the shell, the meteoroid generates an impact wave that starts to propagate throughout the particles of the soil. In turn, the meteoroid body is completely destroyed upon contact with the "space" potting soil and moves ahead in separate fragments losing the remaining energy (Figure 18).

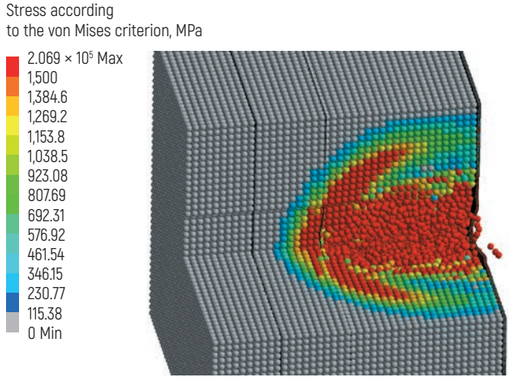

Figure 18 – Impact wave triggered by meteoroid body

Figure 18 illustrates meteoroid body in the form of small particles. At first, the impact wave is generated behind the particles failing to propagate in front of them, although it starts to move ahead upon velocity and energy drop of the whole system. Once the first interference mesh is reached, the wave undergoes the splitting stage. After that, the already split wave re-reflects itself and gets suppressed (Figure 19).

After reaching the second interference mesh, the energy is re-reflected again and drops to zero on the surface of the soil without causing any destructions (Figure 20).

At the end of impact wave propagation, all remaining energy in the system is consumed to restructure wall layers of the soil (Figure 20, indicated in red). However, the partial discharge of the soil into outer space caused by the impact poses a threat for other objects (the pattern and amount of the discharge, as well as spatial scattering trajectories of the particles, are depicted in Figures 18–20).

When such object hits the shell of ECH, mechanical destructions appear only in the first (wall) layer of the soil no more than 5-m thick in which the particles of the stone-ferrite meteoroid are still present. In other cases (if the utilities are arranged above this level), one could claim that the station withstood the impact and preserved the safety of the internal space.

In case of collision with another type of objects (metal beams and other on-orbit elements of different alloys), the shell and the soil on it behave differently.

The most critical threats are prolate (perpendicular to station wall) metal parts.

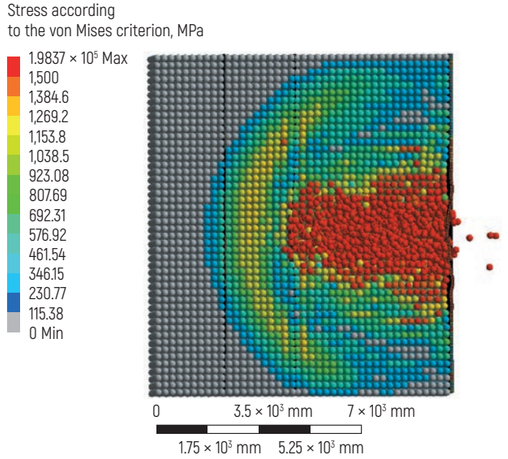

Figure 19 – Distribution of impact wave after propagating through the first interference grating

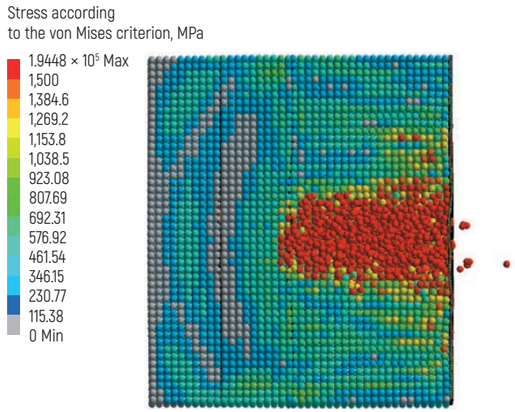

Figure 20 – End of impact wave propagation

Let us consider a 10-kg object traveling along a random trajectory and colliding with the ECH wall at an angle. Figure 21 demonstrates the analytical model.

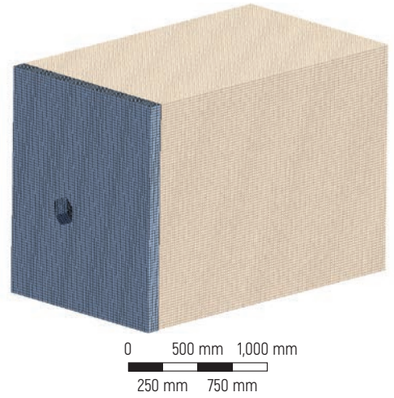

Figure 21 – Analytical model of the main shell impacted by a 10-kg metal spall

An aperture in the shell left upon such impact is significantly different from that formed after the collision with the stone-ferrite meteoroid. In this case, the hole has irregular shape and torn edges (Figure 22). Above all, such result is related not to the shape of the object but to the lack of energy and comparable strain rates of the shell and the threat object.

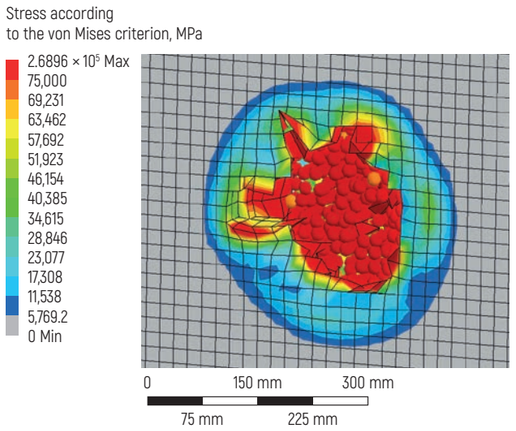

Figure 22 – Pattern of the opening caused upon hitting of a 10-kg metal object into station shell

Propagation of the impact wave differs from the first considered case only in the amount of energy, and hence in the attenuation rate. The wave decays completely at a distance of 1.5 m from the inner surface of the object (Figure 23).

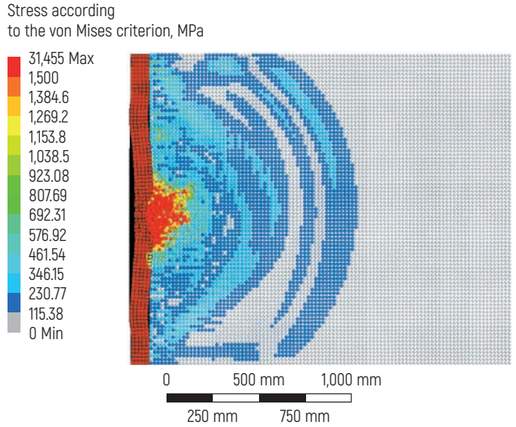

Figure 23 – Propagation of impact wave upon hitting of a 10-kg metal object into station shell

The object itself is partially destroyed when entering the soil and is trapped there while redistributing and compacting it around the place of collision with the shell. On the protective surface layer, space garbage does not cause any significant changes or excessive deformations.

When collided with a large metal object weighing 100 kg and more, the impact wave adopts a more massive pattern but still does not pose a critical threat. See Figure 24 for the analytical model.

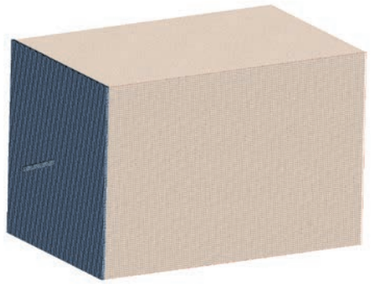

Figure 24 – Calculation model of the ECH main shell at an impact of a metal object weighing 100 kg

The pattern of the resulting opening does not differ from that upon collision with a smaller object. However, the object itself is deformed gravely when it starts to penetrate the soil (Figure 25).

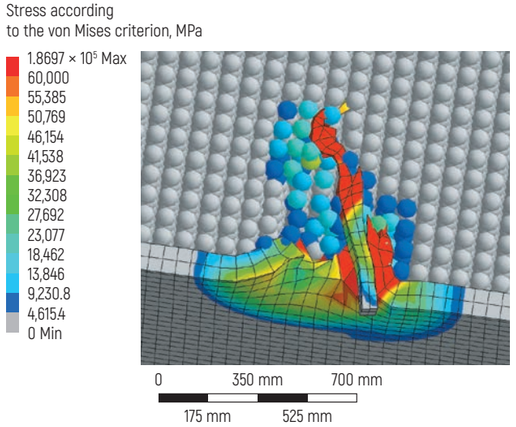

Figure 25 – Deformation pattern of a threat object collided with the ECH shell (general view)

Since the probability of collision with the ECH shell of a space fragment with a conventionally streamlined shape tends to zero (the orbit does not have particles that can remove the sharp edges of bodies with time and the atmosphere to reverse it in the position of least flow resistance), the large object under consideration is estimated as average.

The impact wave has not yet been formed due to a low rate of strain propagation for the soil (Figure 25). The inflicted damage forces the object to collapse quite quickly in the soil and transmit only intrinsic energy in the form of an impact wave propagating throughout the soil. After the object is completely stopped, the impact wave takes the form illustrated in Figures 26, 27.

The impact wave attenuates at a distance of 5 m from the inner face of the ECH shell, also leaving no visible damage to the structures within the station. At the collision point, the soil is partially compacted and its volume is redistributed, although it does not affect the operability of the shell.

It is extremely rare to find the objects on orbit with a substantial difference in weight and velocity from the threats analyzed herein. Thus, we can conclude that the protective structures designed in ECH have sufficient strength.

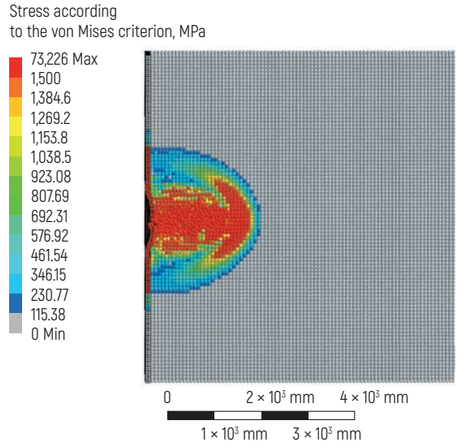

Figure 26 – Start of impact wave propagation

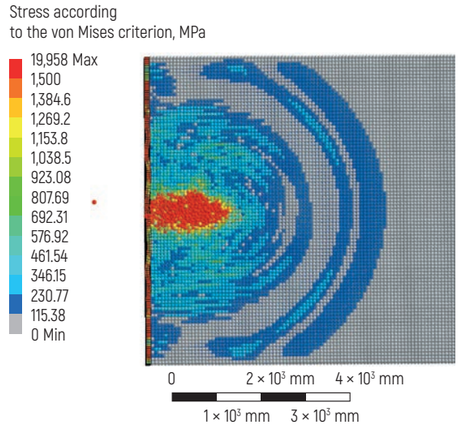

Figure 27 – Attenuation of impact wave

Moreover, in the future, the structure of the shell should be upgraded with vacuum zoning (Figure 28).

The ECH shell can be conventionally divided into two separate compartments with a vacuum insulator in between (Figure 28c). The first module (as viewed from the outer shell) is filled with light hollow spheres that are partially destroyed in case of possible failure of the ECH shell. Destruction of these spheres triggers the absorption of enormous amount of energy and due to the lack of mutual physical connection they easily occupy a new volume. Such type of protection will significantly reduce the impact stress applied to the outer layers of the ECH shell. Plastic dampers (Figure 28b) represent a honeycomb-like structure filling the whole compartment; they act as a horizontal interference tunnel when transferring the impact wave to the aluminum vacuum insulator. The second compartment (as viewed from the soil surface) is equipped only with an additional interference grating (Figure 28d) designed for uniform distribution and re-reflection of the wave that can emerge upon collision of large objects with the outer shell.

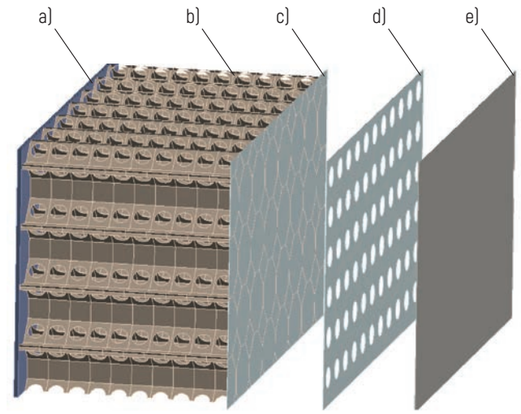

Figure 28 – Perspective view of the structure of the ECH shell (filler is hidden): a – outer shell plating; b – plastic dampers in the form of interference tunnels; c – vacuum insulator; d – interference grating; e – soil surface

As revealed during this research, the shell under consideration has optimum features. It is capable to significantly lighten the structure when replacing a part of the soil with light synthetic materials, thus allowing for a less dense structure and smaller thickness of the outer sheet in the power part of the ECH shell.

Conclusions and Future Work

The calculation revealed high reliability of the ECH shell on Earth orbit. The proposed structure will protect the space construction against threat objects of natural and man-made origin weighing up to a ton. Space garbage of greater weight is rare. However, even in such case the use of the APS and the direction of massive energy at a sufficient distance from the station will allow either changing the trajectory

of a large object or split it into several scattered parts that are not hazardous to ECH.

Penetration through the main shell of the station poses no critical threat in case of vacuum zoning of shell sectors in the soil, including in case of introducing self-healing materials such as self-healing concrete [15] and other similar composites that are being developed now. For this purpose, one can apply soil with the insertion of granules of such material that would fill up the opening in the main shell if steeply heated (due to immense energy transferred upon collision).

Further studies also require deep elaboration of the active protection system capable to ultimately reduce the costs for the shell itself as not subject to any external mechanical exposure.

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UDC 621.039.53/54+624.014+721.01

Shape Memory Effect in the Technologies of Structures Designing Under Zero Gravity Conditions

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The conditions for the manifestation of the shape memory effect for amorphous-crystalline radiation-modified polymeric materials and some metal alloys are described. It proposes engineering solutions that laid down the basis of the following inventions: heat-shrinkable material for transforming metal polymer structures, a transforming solar cell panel, as well as methods for manufacturing a folding antenna and constructing a transforming metal polymer structure in zero gravity, technology for manufacturing a transforming spacecraft structure from polymer materials, methodology for ionizing radiation dosimetry. The main technological and functional ways of practical implementation that ensure the correct designing and effective operation of these engineering solutions under zero gravity conditions are presented.

Keywords:
amorphous-crystalline polymers, shape memory effect, titanium-nickel and copper-aluminum alloys, zero gravity, transforming structures.

Introduction

A number of materials that perform a structural or functional purpose have a unique property called the shape memory effect. This property is characteristic for amorphous-crystalline polymer materials and alloys based on nickel and titanium, copper and aluminum, as well as other components. The shape memory effect in polymers has an entropic nature; in these metal alloys it is associated with the martensitic transition of the crystal structure.

Technologies and Calculated Estimates

For polymers containing crystalline and amorphous phases, as well as those capable of intermolecular crosslinking under the action of ionizing radiation, the shape memory effect is achieved as a result of the following technological operations. First, the crosslinked polymer is irradiated to a dose that may be slightly less than the gelation dose. Then it is heated to melt the crystalline sections and stretched. The next stage is cooling of the polymer under stress until the crystal structure is restored. The material obtained in this way is reheated. At the same time, during the thermal relaxation of the spatial-molecular grid, the polymer tends to restore its original shape. Thermal relaxation characteristics of radiation-crosslinked thermoplastics are determined by the parameters of a three-dimensional macromolecular grid and the conditions of polymer crosslinking.

We have evaluated the dependence of the degree of realization of the memory effect E_r as a characteristic of thermal relaxation properties of thermoplastics on their crosslinking index γ_c. The formula is proposed for calculating E_r [1]:

$$E_r = \frac{l - l_f}{l - l_0} \times 100\ \%,$$

where l_0, l, l_f are the sample lengths as initial, after orientation, and final after thermal relaxation, respectively.

To assess the correctness of determining the structural parameters of a three-dimensional grid based on the equilibrial elastic properties of polymers (using the example of high-pressure polyethylene (HPPE) crosslinked with different doses), the temperature ranges of fulfilling the conditions of the highly elastic state, i.e., the conditions of reversibility of deformations and proportionality of tensile stresses σ of the absolute temperature T, were established. It was noted that, regardless of the density of the three-dimensional structure of the polymer, i.e., the radiation dose absorbed by it, the proportional dependence of σ on T is determined at a temperature exceeding the melting point of the crystalline phase of HPPE by about 40 K. This temperature corresponds to the true equilibrial melting temperature of polyethylene (411... 417 K).

At temperatures closer to the observed melting point (378 K), a sharp decrease in σ was observed, apparently caused by the heterogeneity of the melt, as well as the fact that the preserved crystal formations prevent the manifestation of the relaxation properties of all strained crosslinks of the three-dimensional grid. At the same time, the complete restoration of the geometric dimensions of the samples (E_r = 100 %) after removing the tensile load is observed already at 383... 388 K. The results obtained, as well as the data from the Table for low-pressure polyethylene (LPPE), indicate the correctness of applying the kinetic theory of high elasticity to rare-grid thermoplastics when they are heated to temperatures exceeding the true equilibrium melting point of the polymer.

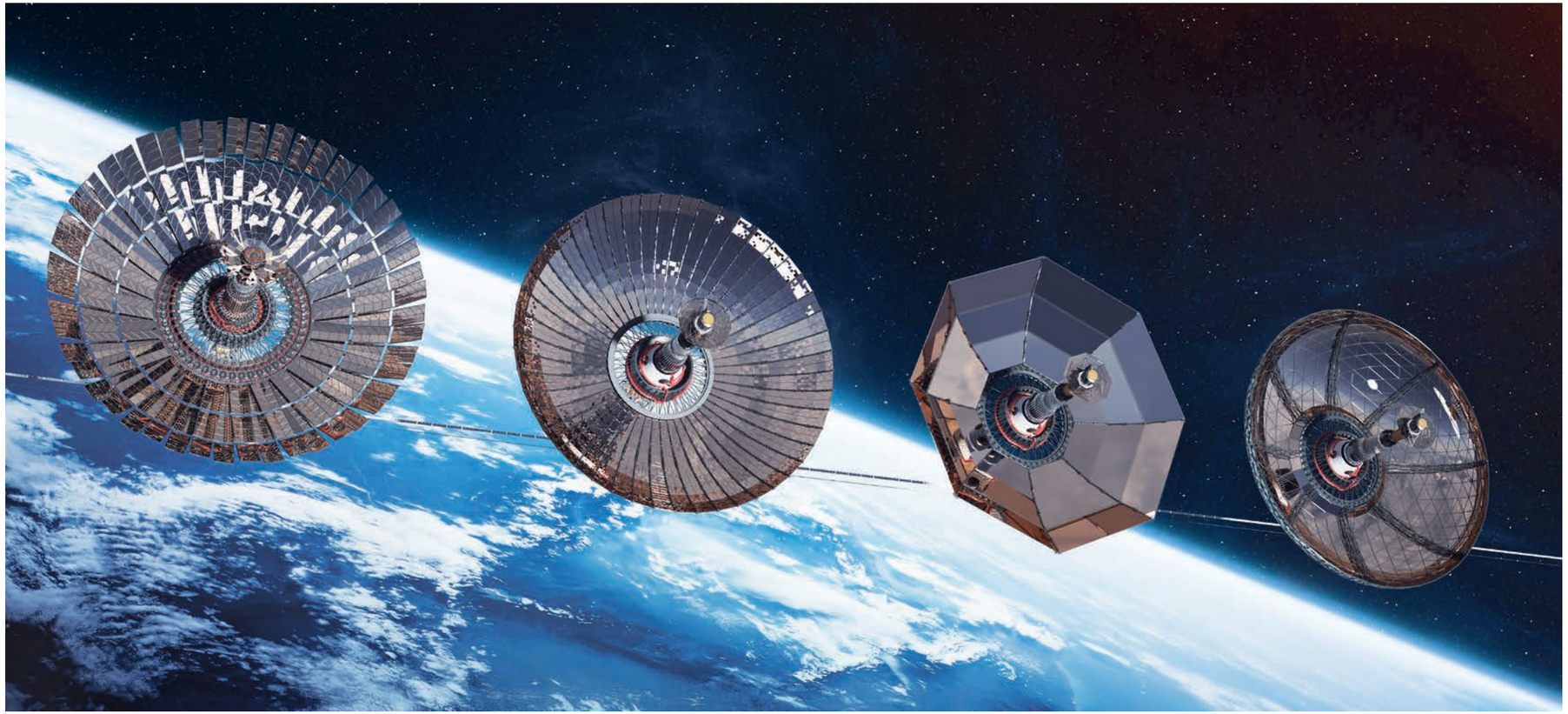

Table – Interrelation of the radiation dose, the crosslinking index γ_c, and the degree of realization of the memory effect E_r of oriented LPPE (degree of extraction λ = 1.5) [1]

Absorbed dose, kGy	γ_c	E_r, %
25	0	0
50	0	0
75	0.26	15
100	0.9	100
200	6	100
400	19	100
1,000	50	100

Examples of Engineering Solutions

The conducted studies of amorphous-crystalline polymers in combination with known data on the conditions for the manifestation of the shape memory effect in various alloys of metal allowed to develop a number of original engineering solutions.

Heat-shrinkable material for transforming metal-polymer structures on a matrix of radiation-modified HPPE reinforced with a titanium-nickel alloy wire lattice. The material allows to create a wide range of structures from it that can transform in zero gravity conditions [2].

A method of manufacturing a folding antenna that has a shape memory effect when folded and restores the original configuration due to thermal radiation from the Sun, for example, in outer space [3].

A method for constructing a transforming metal-polymer structure in zero gravity conditions, including the assembly of its individual components and the structure as a whole on Earth using connecting elements made of a material with memory; folding of a structure into a compact state; delivery to orbit; subsequent deployment of the structure

already in orbit in zero gravity by heating the connecting elements with one or another heat source [4].

A method of manufacturing a transforming spacecraft structure with polymer materials, in fact, allows creating giant metallized sheet and film mirrors in space in Earth orbit, focusing and directing super-powerful streams of thermal radiation from the Sun to the Earth [5].

A transforming solar cell panel characterized by an increased service life and resistance to radiation effects, in which flexible photocells are attached to a panel made of sheet HPPE with shape memory using an adhesive-active γ-irradiated powdered HPPE [6].

Methods of ionizing radiation dosimetry, which make it possible to determine simply and with high accuracy the doses of ionizing radiation absorbed by elements of space structures in a wide range of their values using sensors in the form of film tapes made of a polymer with a shape memory effect. The absorbed dose is determined with a ruler with divisions according to the shrinkage of the film during its thermal relaxation [7, 8].

The above-mentioned engineering solutions can be successfully used in the practical implementation of geocosmic transport systems and space clusters of the EcoCosmoHouse (ECH) type proposed by engineer A. Unitsky [9].

Conclusions

For amorphous-crystalline radiation-modified thermoplastic polymer materials and a number of metal alloys, the manifestation of the shape memory effect is characteristic when temperature conditions change. In metal alloys, this effect is realized as a result of martensitic transitions of the crystal structure, in polymer materials – as a result of sequential technological operations that attribute thermal relaxation properties to the polymer. A formula assigned to assess the degree of realization of the shape memory effect of crosslinked thermoplastics is proposed; the optimal irradiation phases have been determined, ensuring the crosslinking indicators of polymer macromolecules at least at a unit (one) and the degree of realization of the shape memory effect up to 100 %. Based on the conducted research and the determined parameters of technological modes, engineering solutions have been developed (antennas, transforming structures, solar cell panel, dosimeters) that can be successfully used in the practical building and operation of geocosmic transport systems and space clusters of the ECH type proposed by engineer A. Unitsky.

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UDC 629.78

Space-Based Solar Power Plants as Elements of a Distributed Power System

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Space-based solar power plants (SBSPPs) based on solar-pumped fiber lasers that use solar energy provide energy independence and environmental safety. Consequently, an urgent task is to develop options for integrating SBSPP into existing and designed power systems. Possible variants of SBSPP integration into distributed power systems are as follows: to provide electric power to space systems during manned flights to the Moon, Mars, asteroids; for a ground power system; to supply electricity to the Industrial Space Necklace "Orbit" (ISN "Orbit") where solar energy can be used both directly and converted into other types of energy necessary for functioning of all ISN "Orbit" elements dependent on their requirements. While creating and developing solar space power industry, including SBSPP, a vital prerequisite is an international cooperation on all issues related to the effective sustainable development of the mankind.

Keywords:
space-based solar power plant (SBSPP), centrifugal frameless structures, laser emission, MMW radiation, distributed power system, solar-pumped fiber lasers, Industrial Space Necklace "Orbit" (ISN "Orbit").

Introduction

The continuously increasing energy needs of mankind urge to search for new energy sources as opposed to traditional ones (thermal power plants, nuclear power plants, large hydroelectric power plants), which damage the environment and thereby lead to global climate changes and natural disasters. A solution to the problem of a sustainable energy supply may be the development of alternative power industry based on renewable energy sources: the sun, wind, water (except for large hydroelectric power plants), geothermal sources, and biofuels. This energy is inexhaustible; it provides energy independence and environmental safety. Renewable energy sources complement and/or replace traditional energy sources.

Space technology is able to resolve issues related to climate stabilization and substitution of oil with environmental technologies through the creation of aerospace power industry [1–3], where the reliance on solar power industry is seen as a win-win and uncontested choice for the human civilization. It is a common knowledge that the Sun is a huge, inexhaustible, and environmentally friendly power source, and solar power plants provide the most environmentally friendly way to obtain energy.

Space-based solar power plants (SBSPPs) with wireless transmission of electricity to terrestrial and space consumers are the main elements of aerospace power industry both for providing electricity to space systems during manned flights and for a land-based power system in underdeveloped and hard-to-reach regions, where no cable power transmission networks are available (Siberia, Kamchatka, the Far East, as well as regions in the Arctic and the continental shelf). Therefore, an urgent task is to develop options for integrating SBSPP into existing and designed power systems.

Literature Review

The idea of creating SBSPP was proposed by an American scientist, P. Glaser, in 1968. At present, the countries of the European Union, Russia, Japan, the USA, India, Great Britain, Canada, Israel, and China are actively involved in the development of SBSPP. Having advanced in this direction since 2008, China announced, at the end of 2019, its intention to create an SBSPP by 2035 [4]. In Japan, after the accident at nuclear reactors (Fukushima, 2011), a program was adopted to implement SBSPPs by 2040 [5].

The main concepts of SBSPPs arrangement [6] for today are as follows:

- based on SBSPPs placed in low-Earth orbits (Lavochkin Science and Production Association project (Russia));
- based on SBSPPs placed in Lagrangian points (Rocket and Space Corporation Energia project (Russia));
- based on SBSPPs placed in a geostationary satellite orbit (Central Research Institute for Machine Building project (Russia); SolarBird project (Japan); SBSPP project in the 2007 Pentagon program (USA); Solaren project (USA));
- based on lunar space-based solar power plants (LSBSPPs) – using orbital energy relay units (Keldysh Research Center project (Russia); a concept by developer D. Criswell of the University of Houston (USA));
- based on LSBSPPs with a direct energy transmission (Shimizu Corporation project (Japan)).

Solar power industry is traditionally divided into:

- ground-based solar power plants (SPPs) that are, in their turn, classified depending on the range of operating temperatures into low-temperature (up to 600 K, using photoelectric converters (FECs)) and high-temperature (theoretically, up to 6,000 K, practically – 1,000 K and 2,500 K, using machine and thermionic electric generators). Disadvantages of ground-based solar power systems are: their location in territories with serious energy potential, however, distant from consumers; dependence on weather conditions, as energy losses reach up to 60–90 % when solar radiation passes through the atmosphere; huge areas required by high-power SPPs; the impossibility of their operation at night and in the evening reduces the system efficiency by several times [7, 8];
- SBSPPs.

The scope of an SBSPP includes [7, 8]:

- a space platform for solar energy collection and conversion into electrical energy (2, 3, Figure 1);
- a channel for converting electrical energy into microwave or laser energy for its further transmission to the Earth (5, Figure 1);
- a network of ground points for receiving microwave or laser energy with its subsequent conversion into electrical energy, where electricity can be accumulated for its further exchange with other points (6, Figure 1).

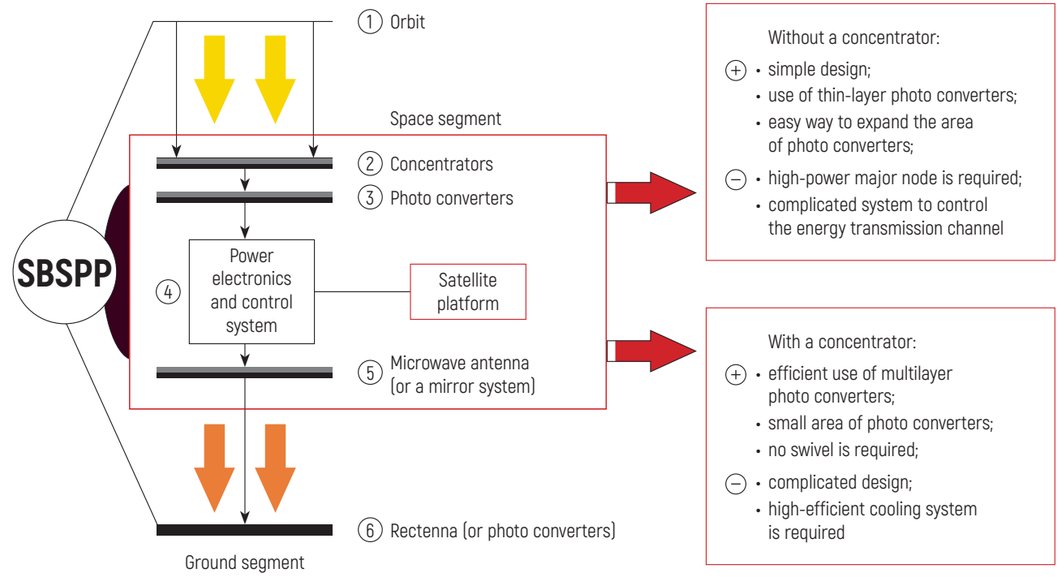


Figure 1 – SBSPP structure: a – configuration; b – classification

SBSPPs have no disadvantages of ground-based SPPs [9–12]:

- energy is available virtually around the clock and does not depend on weather conditions;
- energy can be transmitted to absolutely any area on the surface, including Northern territories, which makes the use of SBSPPs relevant;
- no mineral resources of the Earth are consumed (coal, gas, oil, etc.);
- there are no issues related to emissions of CO_2 or other air pollutants; there are no problems with a disposal of radioactive and/or processed waste;
- ground receiving points can be located on rooftops or water platforms, which provides for an efficient use of the area. A microwave (or laser) beam can be easily transferred from one receiving ground point to another providing quick switching over remote users.

SBSPP advantages and disadvantages are determined by the choice of an orbit (Figure 2).

See [7] for analysis of advantages and disadvantages of orbit types where SBSPP placement is designed; recommendations are provided in regards to their use (see the "Notes" column in the Table).

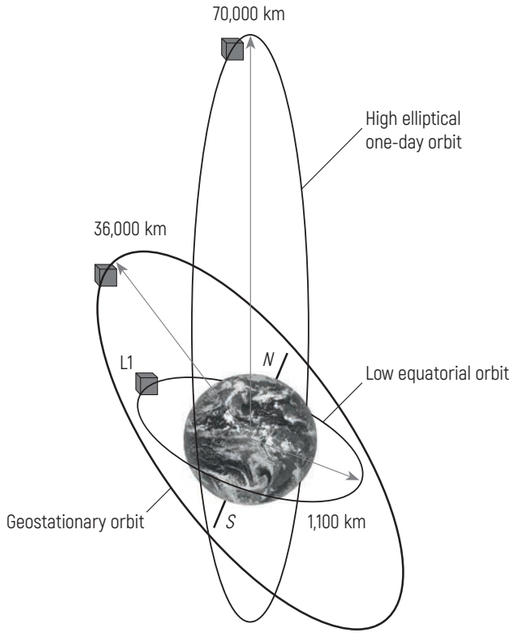


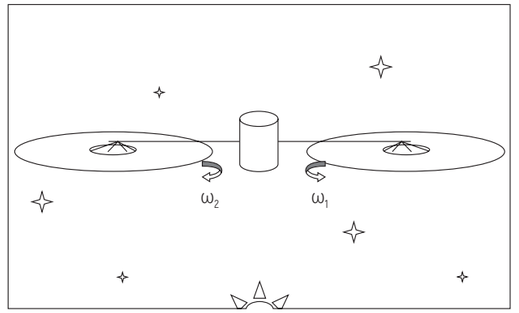
Figure 2 – Types of orbits [1]: L1 – positioning at the Lagrange point

Table – Advantages and disadvantages of orbit types for SBSPP operation [1, 7]

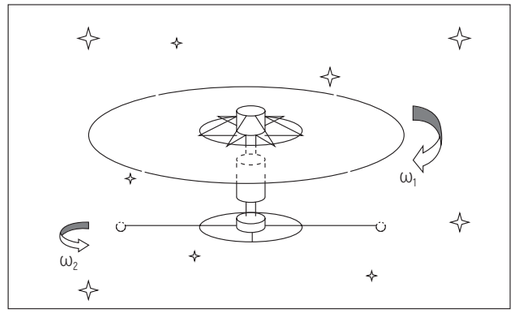
Type of orbit	Advantages	Disadvantages	Notes
LEO (circular orbit)	Short distance Small antenna of spacecraft (SC) Low costs of placement into orbit	Large intervals in energy transmission Large number of receiving antennas Complicated management	Suitable for a demo SBSPP optimization
GEO (geostationary orbit)	Continuous energy transmission A single receiving antenna (rectenna) Simple management	Long distance Large SC antenna High transmission costs Troublesome maintenance	Suitable for a commercial SBSPP
SSO (solar synchronous orbit)	Easy pointing of the panels to the Sun and the SC antenna pointing to the rectenna on the Earth	Complicated management Large number of rectennas	Suitable for a specialized SBSPP
L1 (positioning at the Lagrange point)	Continuous energy transmission Simple management A possibility of placing a large number of SCs	Large distance Large SC antenna High transmission costs Troublesome maintenance	The next step in development of future SBSPPs

The choice of the orbit and the design of the SBSPP solar cell panels (SCPs) determine its power and schemes of compensation for the angular momentum of the rotating SCP [9–12] (Figure 3):

1) two rotating SCPs with parallel axes of rotation are located on the opposite sides of the satellite platform (Figure 3a);



a)



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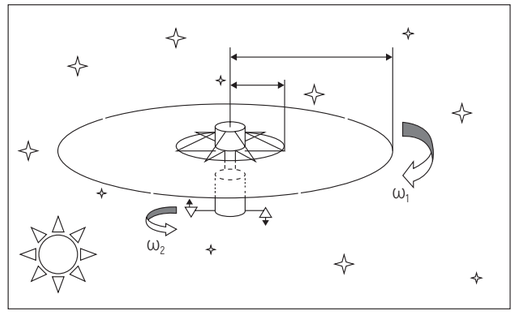

c)

Figure 3 – Schemes of compensation for SCP kinematic momentum [11]

2) one rotating SCP with a counter-rotating flywheel in the form of weights on a cable or a ring cable system (Figure 3b), and two coaxially counter-rotating cell panels that do not shade each other;

3) one rotating SCP with a kinematic momentum compensation with fuel from the attitude control engines (Figure 3c).

The first option that contains a "frame" element in the form of a sliding bar possesses disadvantages of frame and frameless systems. Hence, the second and third options are preferable. The third option is simpler from the technical point of view than the second one, since it can engage an uncontrolled scheme of the disclosure unit with one electric drive of rotation; however, due to a limited fuel volume on board the satellite platform, it can be considered mainly in relation to satellite platforms of a small and medium size. The second option is the most versatile, although more complicated, since it uses two fully controlled electric drives (rotary and release drives). It is applicable on any satellite platform [11].

Advantages of centrifugal frameless SCP space structures over frame analogs [9–12] are as follows:

- absence of a rigid frame that accounts for up to 50 % of the entire system cost;
- insensitivity to meteorite hazard;
- admissible reorientation (tracking the Sun) on the gyroscopic principle without an expenditure of a working medium due to the fact that the centrifugal system itself is a heavy gyroscope;
- small volume of stacking during transportation;
- possibility of efficient ground development, automated deployment, and retraction in the orbit if it is necessary to change the dislocation;
- unique domestic experience of ground and orbital development.

The SCP capacity depends on its weight and dimensions. When designing, it is important to solve the problem of increasing the area of the receiving surface of SCP while minimizing its weight. The most widely used solution to this problem is film SCPs. Currently, the development of film materials for SCPs is underway, taking into account the achievements in the field of nano- and metamaterials [13–15].

The well-known SBSPP concepts [4] foresee for the use of semiconductor photo converters of solar energy into electrical energy. These semiconductors are located in a geostationary or other orbit perpendicular to the solar rays. Electricity collected from the area of all photo converters is converted into a microwave or laser signal of various

wavelengths that is not absorbed on the way from space to Earth and is transmitted to a terrestrial rectenna.

Consequently, creation of frameless centrifugal SBSPP structures can guarantee a significant reduction in financial costs and time for project implementation when using space solar power systems as compared to alternative schemes in the past [10–12]. The most important mission of SBSPPs (except for the task of collecting and accumulating electrical energy) is a high-quality transmission of the received electricity to space and ground consumers with a formation of distributed hybrid energy systems.

Method Description

When integrating an SBSPP into existing and/or designed power systems, the arising issue is high-efficient wireless power transmission. Microwave and laser emissions are currently being considered.

The acceptable frequency range of microwave emission, based on the results of multi-year scientific research, that is most suitable for transmitting high power with minimal energy losses when passing through the Earth's atmosphere, is grouped near the carrier frequency f = 2.45 GHz. In this case, the SHF wavelength is 10–12 cm. While passing through the sequence of the ionosphere and atmosphere, it is practically not distorted. Phase front losses of 3–7 % are observed only during intense precipitation (100–150 mm/h). For shorter wavelengths, damping increases rapidly; for longer wavelengths, the size of the antennas increases.

Laser emission (as contrasted to microwave emission) exhibits energy transfer losses due to the presence of aerosols and atmospheric turbulence. Critical are energy losses on ground-based with capacitive SCPs with an efficiency of 40–60 %. Figure 4 shows that when the emission line of high-efficiency fiber lasers is shifted to the ranges of 1,000–1,100 nm and 1,300 nm, it enters the atmosphere transparency zone, which indicates a way to increase the energy transfer efficiency of the laser method and, consequently, a possibility to increase its performance factor [15–18].

Significant advances in the development of fiber lasers during the recent decades have attracted the space solar power plant developers' attention, which gave rise to the SBSPP laser concept. Fiber lasers are capable of producing a narrow beam five orders of magnitude smaller than the area of a SHF beam on Earth. The filamentous nature of a fiber laser makes it possible to use efficiently centrifugal forces in order to form a frameless flat area of fiber lasers perpendicular to the solar rays (Figure 5).

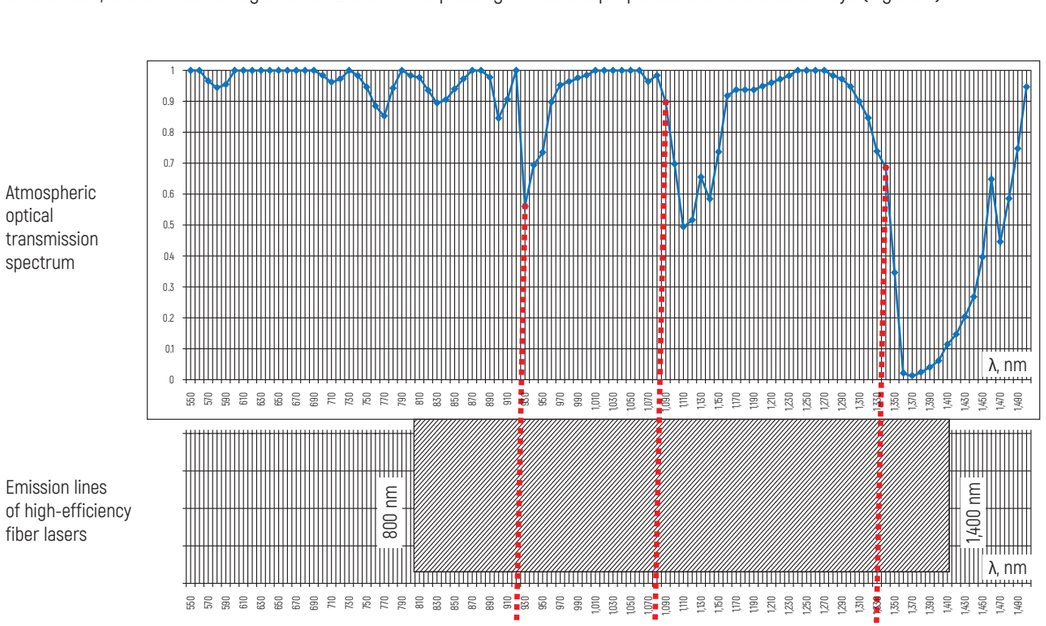

Figure 4 – Comparison of the atmospheric optical transmission spectrum and emission lines of high-efficiency fiber lasers [18]

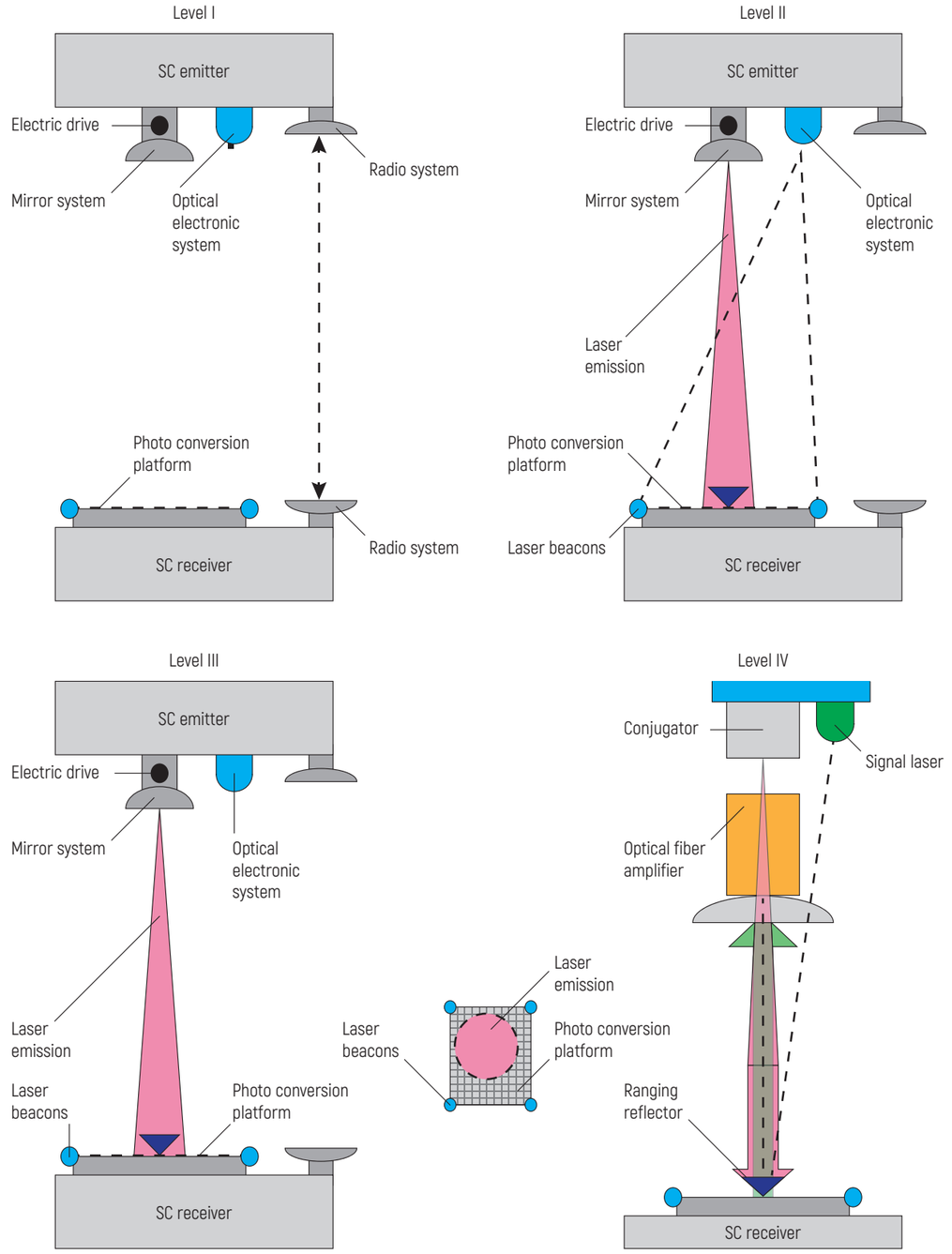

Figure 5 – Targeting scheme for laser power transmission channel from SBSPP [11]

Accordingly, advantages of solar-pumped fiber lasers in contrast to SHF systems [10, 16–18] are as follows:

- absence of a rigid frame, which greatly simplifies and reduces the cost of the design;
- solar-pumping of a fiber laser eliminates the need to use SCPs, and the SBSPP weight can actually be reduced by 2–3 orders;
- divergence of the laser beam that is five orders less (10^{-6} rad) as compared to a SHF signal. Consequently, the area of the receiving rectenna decreases;
- achievement of real miniaturization of the element base (light power of 50 kW is transmitted through a fiber with a diameter of 250 μm);
- life utility exceeding 100,000 hours;
- possibility to receive energy in high-latitude regions of Russia from an SBSPP located in a geostationary orbit;
- Russian manufacturers of optical fibers are holding the leading positions in the world now (85 % of world production).

The environmental hazard of an SBSPP with laser emission in the infrared (IR) wavelength range is significantly lower, as compared to an SBSPP with SHF emission due to the following reasons [10, 11]:

- lower biological impact, since an SHF beam passes (similarly to a radio signal) through a biological structure and exerts a volumetric effect on it, while an IR beam (like in the light wavelength range) produces only a surface impact that is effectively shielded;
- local reception and an energy impact on a significantly smaller reception area;
- fundamental admissibility of defocusing the laser beam to any required level if it is impossible to target it accurately at a receiving rectenna.

Figure 6 presents a principal layout scheme of a deflector – a single centrifugal SBSPP module based on solar-pumped fiber lasers [11]. In an actual scheme, the density of fiber lasers and the diameter of the space they cover are much larger to achieve the required power. The principal

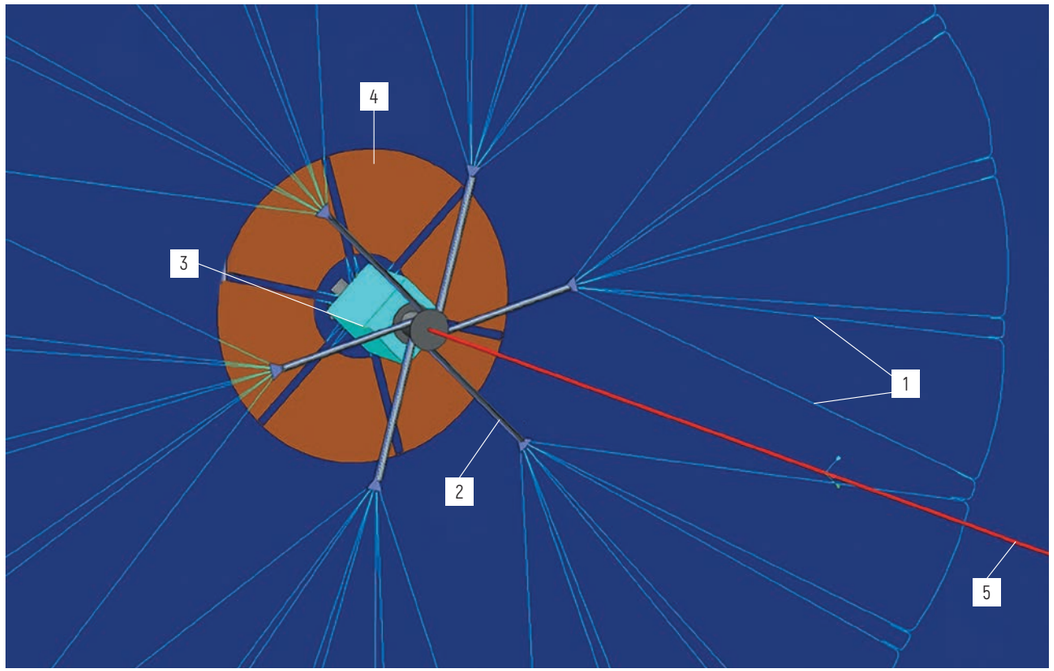

Figure 6 – Layout scheme of a deflector – a single SBSPP module based on solar-pumped fiber lasers:
1 – fiber laser; 2 – rod deployable from a lenticular profile; 3 – instrument container;
4 – centrifugal SCP for internal needs that functions as a counter-rotation flywheel; 5 – laser beam

positive difference of this scheme is the absence of SCPs and, accordingly, a cycle of converting solar energy into electrical energy on SCPs, as well as a cycle of converting this electrical energy into laser one on solid-state lasers. Solar pumping powers the laser directly [18]. In this case, both two conversion cycles with concomitant losses are excluded, and the design is simplified greatly, with its weight specifications reduced by more than 10 times. A new direction emerges for improving SBSPPs that is associated with increasing the efficiency of laser solar- pumping (lowering the lasing threshold, shifting the wavelength into the transparency window of the atmosphere) and vibrations suppression of a platform with rotating structures.

Due to the lack of special-purpose financing for the development of solar-pumped fiber lasers in Russia, the design shown in Figure 6 cannot be implemented. The main argument is the lack of lasers with sufficient efficiency. Such lasers have been developed for 20 year in Turin (Italy) (Boetti N. and al.). However, there has not been any information about new achievements in this area. Reference [19] relates about new carbon nanotube-based devices developed by engineers at the Georgia Institute of Technology (USA). With this design of nanotubes, it is possible to create both efficient SCPs and a solar-pumped laser with an efficiency of up to 50 %.

The following target-oriented variant of SBSPP application have been considered:

- power supply for space users (flights to asteroids, the Moon, and Mars) (Figure 7) [11, 20–25];
- power supply for terrestrial users. Stratospheric segments (airships, balloons) will be engaged to build and integrate an SBSPP into ground power systems (channels 1, 2, Figure 8) [2–8, 11, 19–25].

Within this approach, it is suggested to consider the stratospheric segment as an independent element of the energy transfer system (Figure 8) when a signal from SBSPP is absent, and solar radiation is present. That is, in addition to the equipment that receives a signal from SBSPP, a system is installed on the stratospheric segment to convert solar energy into laser and/or SHF emission.

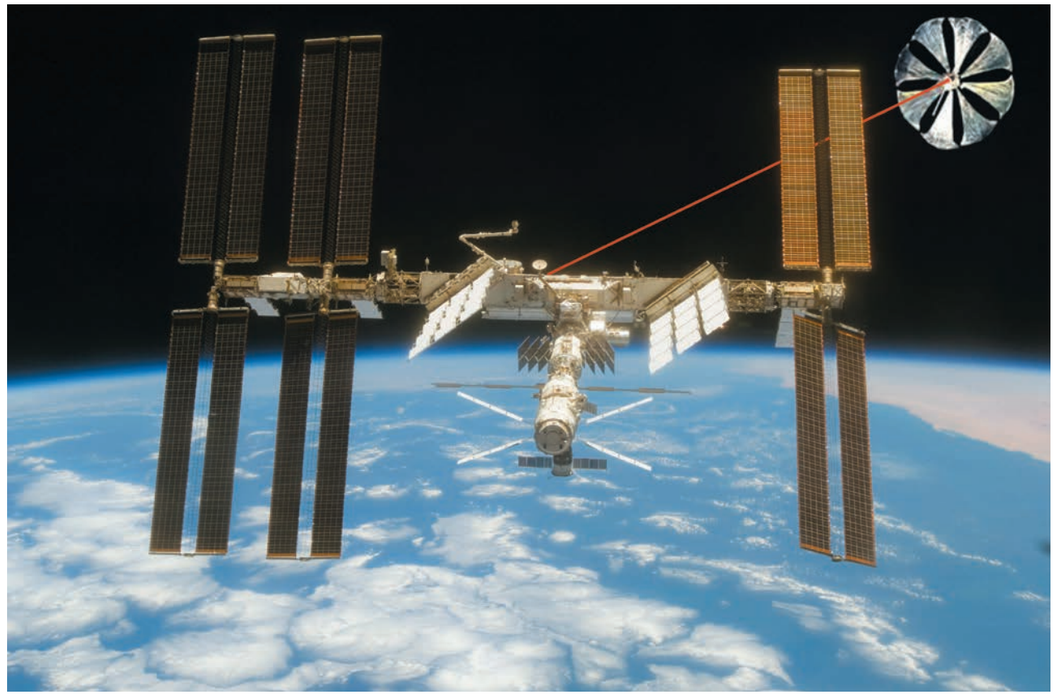

Figure 7 – International Space Station power supply
via a laser beam from a centrifugal SBSPP [25]

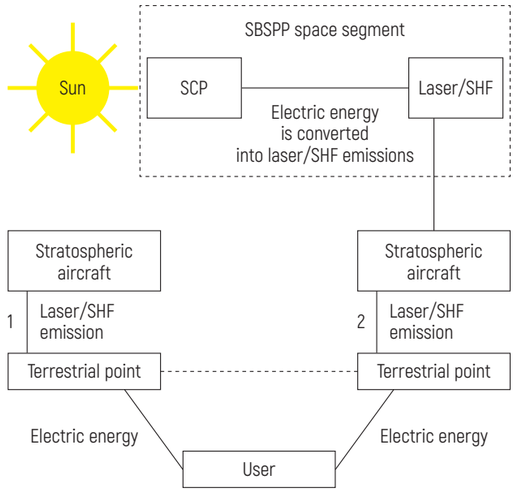

Figure 8 – SBSPP integration into terrestrial energy systems via stratospheric segments

An option of connecting the stratospheric segment to terrestrial point with a wire cable is also being considered, causing many disputes on its expediency due to safety and technical implementation issues [11, 25].

It is worth mentioning one more option for SBSPP operation – as centrifugal reflectors for illuminating the Arctic regions with sunlight reflected from the orbit (Figure 9). The matter was under practical development during the implementation of the Znamya-2 space experiment program [18], where single SBSPP modules based on solar-pumped fiber lasers were employed (Figure 6). Due to a low divergence of the sunlight, the illuminated area can be highly localized. From the ecological point of view, illumination from orbit entails a danger to disturb the prevailing conditions of biorhythms for flora and fauna that have been built for centuries. Such illumination can be practiced in high-latitude regions in order to normalize human biorhythms during the polar night.

In 1995, engineer A. Unitsky published a scientific monograph "String Transport Systems: On Earth and in Space" (reprinted in 2017 and 2019 [26]), where the ideas of the General Planetary Vehicle (GPV) and the Industrial Space Necklace "Orbit" (ISN "Orbit") were presented for the first time.

The GPV is a reusable geocosmic spacecraft for non-rocket industrial exploration of near space made in the form of a torus encircling the Earth in the equatorial plane that provides industrial cargo and passenger traffic from Earth to near-Earth equatorial orbits and vice versa; it is based on the only possible (from the physical point of view) environmentally friendly geocosmic transport technology with minimal energy consumption [26].

When the GPV is launched, the vehicle body and anything attached to it (the load, linear electric motors, etc.) start rotating in the same direction as the upper endless belt until it reaches the peripheral speed equal to the first cosmic velocity; at the same time, its radial velocity will drop to zero according to the conservation law of the angular momentum of the system [26]. Having reached the destination, at an altitude of 400–600 km, the cargo and passengers are unloaded onto the ISN "Orbit" that is an orbital transport infrastructure and industrial residential complex covering the planet in the equatorial plane at a specified altitude (for instance, 400 km) with a respective length of 42,520 km (for the altitude of 400 km); where "beads" are paired cargo and passenger gondolas delivered into the orbit with an interval of about 500 m (in the amount of about 160,000 pieces with a total weight, together with their cargo and passengers, equal to 10 mln tons) that are connected to each other with a "string" – string orbital pathways and other communication (energy and information) lines [26] (Figure 10).

Weight is known to be missing in the orbit. Consequently, string orbital pathways can be considered as tensioned strings, for example, made of reinforced aluminum, that transfer electrical energy between the ISN "Orbit" gondolas. It is planned to create an infrastructure around the gondolas in the form of various industrial structures (factories, manufacturing, and power plants, etc.), as well as residential space settlements for the ISN "Orbit" personnel – EcoCosmoHouses (ECHs) [26, 27].

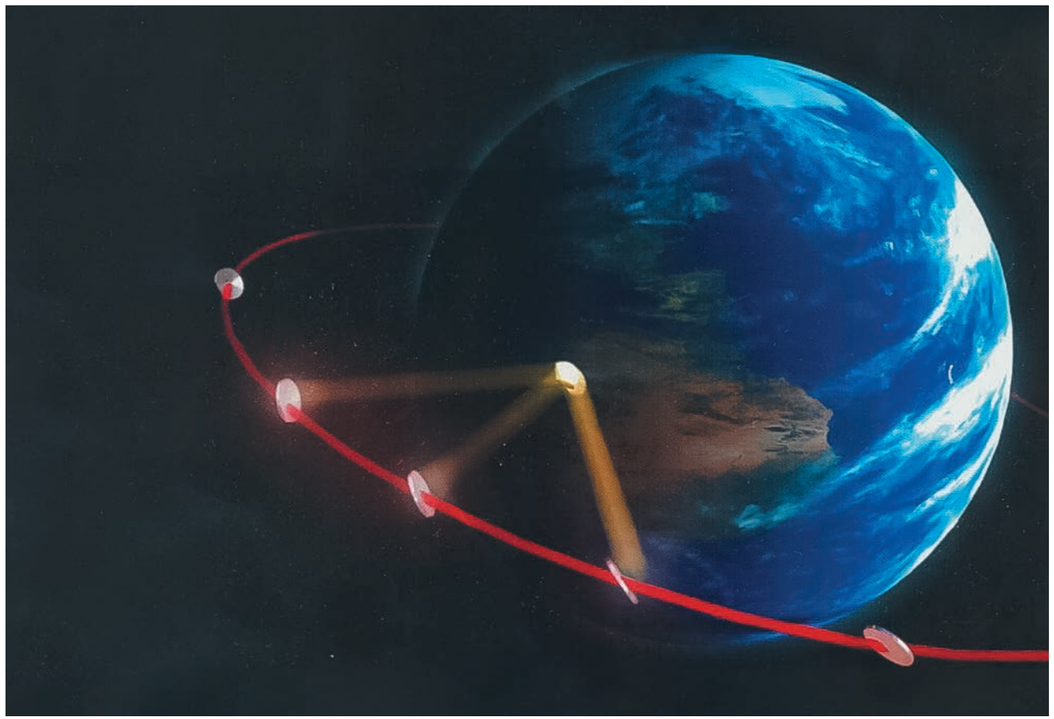

Figure 9 – Terrestrial area illumination by reflected sunlight from the orbit

Figure 10 – ISN "Orbit" [27]

Outcomes and Analysis

The main types of energy important for the ISN "Orbit" life support are electrical, mechanical, thermal, and light energy. Solar radiation is the only primary source the energy whereof can actually be converted into all useful types of energy directly in the orbit. Direct or concentrated solar radiation can be converted into thermal energy of heated bodies, and then, via a direct or mechanical transformation, into electrical energy. Temperatures of heated bodies depend on the incident radiation density and the arrangement of heat transfer processes, including the reverse thermal radiation from the surface [28].

It is proposed to use film SCPs on gondolas and solar-pumped fiber laser-based SBSPP instead of creating power plants in the form of "crystals" around the ISN "Orbit" gondolas (Figure 11), which will reduce the weight and size of the gondolas, and the excess electrical energy will be transferred from the SBSPP to the Earth via stratospheric segments, thus creating a hybrid energy system of the Earth.

Figure 12 presents a proposed integration of a solar-pumped fiber laser-based SBSPP with the ISN "Orbit" to provide the latter with electrical power that can be used both as electrical energy and converted into mechanical, thermal, and light energy for a sustainment of the ISN "Orbit" gondolas depending on their needs.

Energy transfer occurs when SBSPP approaches the orbit where the ISN "Orbit" is located, by sequentially targeting the laser energy transmission channel to the rectennas of the gondolas that are within the accessible range. The process of energy transmission itself is controlled by the personnel or automatically with the ISN "Orbit" information management system.

Conclusions and Future Work

To meet the increasing energy needs of the mankind, an international composite application of distributed alternative power industry is required (including space solar power industry, the basis whereof is an SBSPP) that would supplement and/or replace the conventional energy sources, – for the purposes of sustainable development of the mankind, reducing damage to the environment that leads to a global climate change and natural disasters.

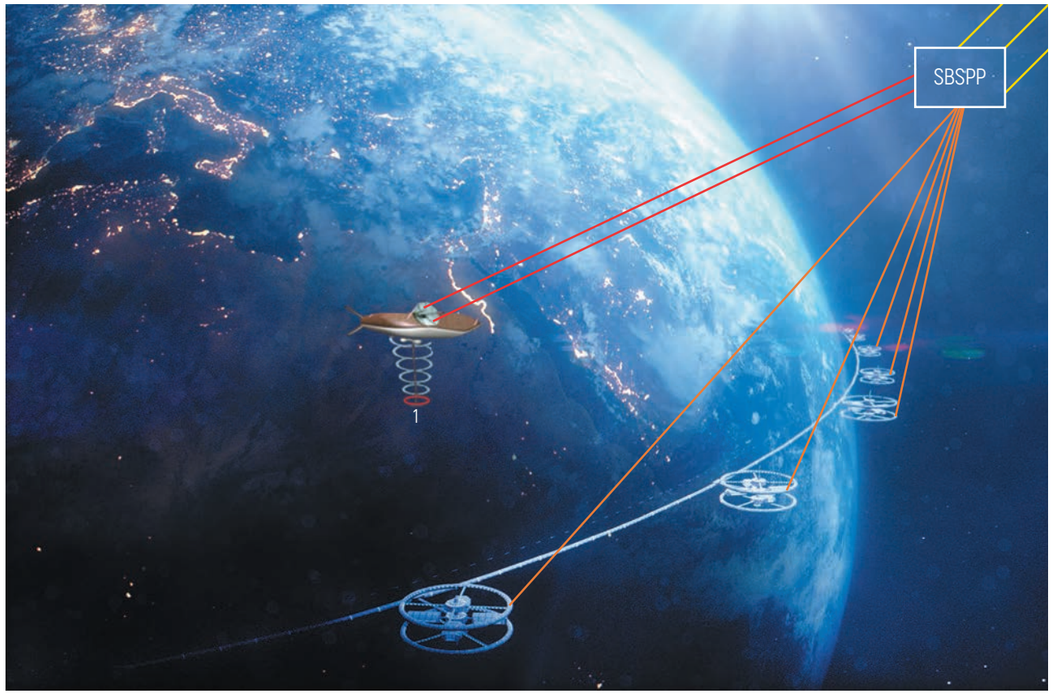

Figure 11 – Approximate scheme of interaction of the ISN "Orbit" with SBSPP on solar-pumped fiber lasers: 1 – rectenna (terrestrial point)

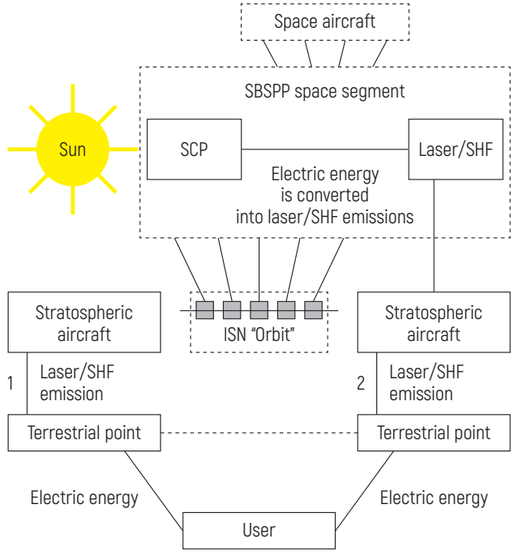

Figure 12 – Proposed integration between a solar-pumped fiber lased-based SBSPP and the ISN "Orbit"

Sustainable provision of the ISN "Orbit" with all types of energy (electrical, mechanical, thermal, and luminous) by converting directional laser emissions from a solar-pumped fiber laser-based SBSPP with minimal losses under vacuum is possible by means of integrating such SBSPP into the ISN "Orbit" energy system. An SBSPP located on a different orbit may be used for other purposes – power supply for long-distance flights, illumination with a reflected sunlight and power supply of high-latitude regions, regions of the Far North, etc.

Taking into account the advances in the field of nano- and metamaterials for the development of film SCPs and SBSPPs improvement in the field of solar pumping of lasers, we are planning for the future to consider the interaction between an SBSPP (or a set of SBSPPs located in different orbits) with the ISN "Orbit" in order to create a distributed energy system designed to provide needs of a multi-orbital transportation structural complex, and a subsequent development of an information management system for generating, receiving, and transmitting energy.

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UDC 575.167

Problems of Human Genetic Variability in an Enclosed Ecosystem

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The peculiarities of human existence in an enclosed ecosystem devoid of the interchange of substances and energy with the external environment are considered. The study took into account population indicators of human development dynamics in isolated conditions. The theoretical aspects occurring within a separate population (panmixia, gene drift) are analyzed. Possible programs for the artificial maintenance of population dynamics in an enclosed ecosystem of EcoCosmoHouse (ECH) are proposed.

Keywords:
enclosed ecosystem, human population, polymorphism, variability, hereditary diseases, gene pool, population structure, hereditary diversity, cryopreservation, EcoCosmoHouse (ECH).

Introduction

One of the considered concepts of human stay in EcoCosmoHouse (ECH) is associated with permanent residence under the conditions of an enclosed ecosystem, which in turn leads to the emergence of an isolated population of people.

A population implies the ecological, morphophysiological, and genetic integrity of individuals of the species. In the evolutionary process, it is considered to be unified, i.e., it is an independent developing structure, an elementary evolutionary unit.

The usual human population tends to accumulate heterozygous traits [1]. Such a condition of the traits allows to acquire resistance to genetic diseases.

Currently, more and more scientific justifications are being provided confirming that in the future (due to irreversible changes in the Earth's biosphere), a person will have to be isolated for a long period [2–4]. This can happen during a long stay in space expeditions or in case of necessity of living in enclosed ecosystems (for example, in ECH) within the Earth's orbit, but outside the Earth's biosphere [5].

With prolonged existence in enclosed ecosystems, people will face a number of genetic factors, such as hereditary diseases, gene drift, adaptation, variability, and other evolutionary processes.

The scientific novelty of this research is the proposal to create a genetic bank in order to avoid closely related interbreeding and the strive of the population to a heterozygous state, i.e., to the same development of population size and its genetic diversity, as under the conditions of the Earth.

Human existence within an enclosed ecosystem will be associated with two fundamental properties – heredity and variability.

The genomes of all people have minimal differences. The pronounced population, ethnic, and individual diversity of genomes is conditioned by all kinds of recombinant variability, leading to genetic polymorphism.

Variations in the primary structure of hereditary information caused by polymorphism form the basis of a unique genetic portrait of each person and determine his/her special biochemical profile. The extreme expressions of hereditary human variability are hereditary diseases. The consequence of polymorphism, as well as variability, is the predisposition of each person to certain chronic diseases.

The purpose of this research is to study the problems of human existence in an enclosed ecosystem at the level of genetic information and its heredity; to present a program for the effective maintenance of a healthy population under the conditions of an enclosed ecosystem.

Literature Review

Basic Concept of Polymorphism in the Human Population

Human polymorphism occurs in a single panmictic population; it is possible with two or more different phenotypes. Phenotypic features of a population may be normal or abnormal.

The manifestation of polymorphism within the population in ECH will take place according to four main processes: genomic, chromosomal, transitional, and balanced (Figure 1) [6, 7].

On planet Earth, the population is characterized by small genetic differences both at the population level and for individual genomes. Genetic variability manifests itself in the form of clustering of geographically close sets of genera spread over the entire territory of the Earth's land [8].

People in a population differ by 10–15 % among themselves. In the course of settlement, under the influence of migrations, genetic drift, and abrupt changes in the effective number of biological species, structures of genetic diversity were formed [9, 10].

In addition, natural selection has determined genetic diversity on a global scale throughout the entire existence of mankind. An equally important role was played by the adaptation of a population to the local habitat.

Diversity and Variability of the Human Gene Pool in an Enclosed Ecosystem

The population includes individuals with both dominant and recessive traits that are not under the control of natural selection. According to G. Mendel's law, dominant traits suppress recessive ones; when splitting by phenotype, descendants of the second generation, i.e., conditionally pure lines, have a superiority in the number of prevailing indicators, which is 3/4 of the part. However, in a population tending to accumulate heterozygous individuals, the dominant allele cannot completely displace the recessive one.

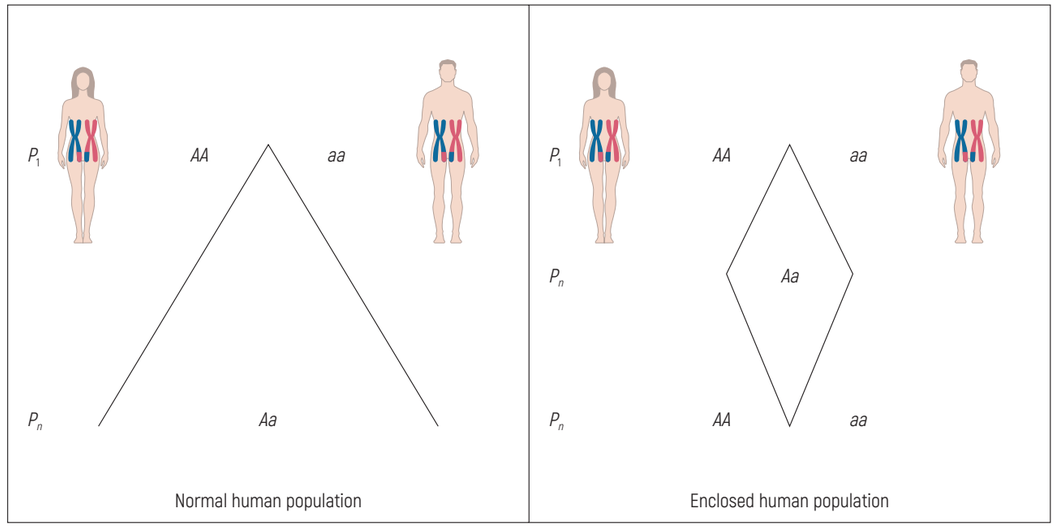

Figure 1 – Tendency of human population to a heterozygous state:
A – dominant trait; *a* – recessive trait; *P* – parents (P_1, P_n, etc.)

This pattern is considered by the Hardy – Weinberg law. Such a population is characterized by a greater number, free crossing (panmixia), absence of mutations and natural selection [11].

The problem of a population staying in an enclosed habitat is that the Hardy – Weinberg law has a number of exceptions. For example, the number should be large enough, theoretically unlimited in size. This is not possible in the ECH population. This means that in a small enclosed population, the ratio of individuals with dominant and recessive traits will be disrupted; as a result, a transition to a homozygous state will gradually occur.

The influence of elementary evolutionary factors on the change in the gene pool of the human population is reduced to the action of the mutation process, migrations, gene drift, natural selection [8].

The problems under consideration are related to the infinitely long existence of a person in ECH. The human population in an enclosed ecosystem will be isolated. Such separation leads to intermarriages, inbreeding, and gene drift, which entails the manifestation of recessive pathological genes in a homozygous state and contributes to an increase in mortality. In the populations of the Earth's biosphere, this can be avoided due to migration and a number of other factors.

Migration is considered as one of the main dynamics factors that changes the level of genetic diversity in population genetics [12]. The "island" model of population structure, which is particularly close to ECH, is a set of partially isolated populations exchanging migrants (the "isolate" model). The inbreeding indicator is combined with demographic parameters in a similar way. Consequently, on the one hand, increased migration between subpopulations lowers the level of interpopulation diversity, and on the other hand, by reducing the frequency of autosomal recessive pathologies, it lowers inbreeding and the level of genetic baggage in the population, without mentioning particulars.

If we consider urban populations, they are greatly influenced by such a factor as relocation between remote cities, which the ECH residents will be deprived of. Migration increases not only the number but also the hereditary diversity of the population. The intensity of movements and the qualitative composition of migrants affect the changes in the gene pool that occur within one generation. The higher the proportion of migrants and the greater the differences between them and indigenous population, the greater is the genetic effect.

In an enclosed ECH population, the number of migrants can be replaced with genetic material from the genebank (Figure 2).

The selection of genetic material in each generation of the human population will preserve the balance of dominant and recessive traits, as well as the tendency to maintain a heterozygous state of the population size. In order to avoid closely related crossbreeding and obtain the most diverse genotypes, the selected genetic material can be used only after the hundredth generation. Prior to the application of the selected genetic material of all previous generations of ECH, it is assumed to use a pre-created genebank taken (according to certain criteria and features) from various human populations on planet Earth.

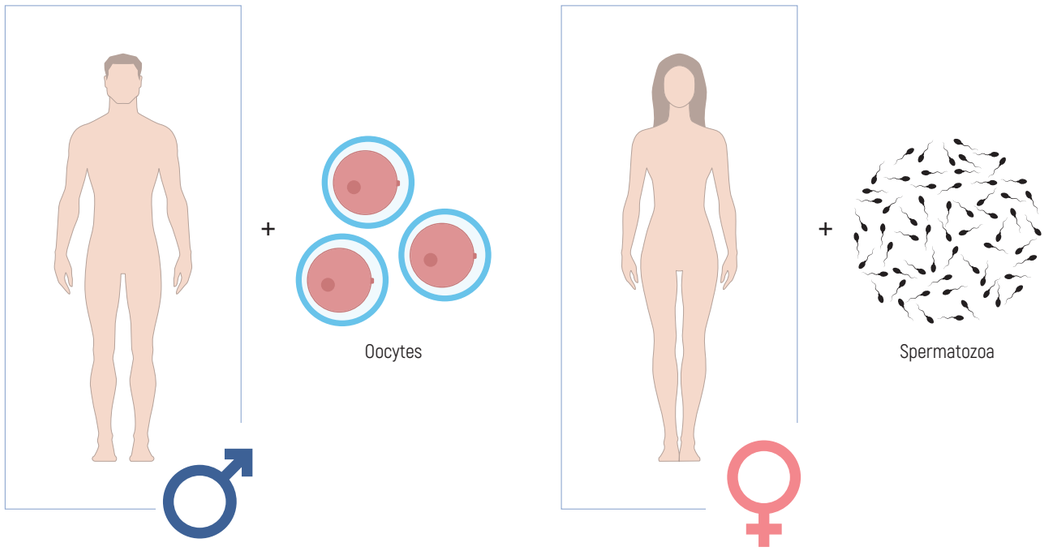

Figure 2 – Diagram of the movement of genetic information in an enclosed ECH population

Hereditary Human Diseases

With an autosomal dominant type of inheritance, the manifestation of the gene in a heterozygous state is more common in women, and immediately in the first generation. Freckles, brachydactylia, cataracts, bone fragility, chondrodystrophic dwarfism, polydactyly are inherited by this type. In addition, such traits as pigmented dermatosis, keratosis, blistering of the feet, brown enamel of the teeth are inherited.

With the mutation of sex-linked traits, the phenotype manifests itself only in the homozygous (recessive) state of genes in individuals of both sexes (more often in men). As a rule, healthy parents, but carrying a recessive gene, have sick children with a 50 % probability. At the same time, only boys will be sick, and girls are 50 % likely to be carriers of the recessive gene. However, the trait does not manifest itself in every generation. Thus, hemophilia, Duchenne muscular dystrophy, color blindness, myopathy, etc. are inherited. With the Y-linked type, only men are sick. These traits are determined by holandric genes (for example, hypertrichosis, azoospermia, ichthyosis) [13, 14].

The frequency of diseases is directly due to the difference in the frequencies of alleles in populations. The main factors of population dynamics forming the picture of population differences in the burden of hereditary diseases are gene drift and the effects of parental traits [15]. With a stable population size, gene drift plays a leading role. Abrupt changes in effective numbers (population waves) reinforce the role of gene drift. The importance of natural selection in the differentiation of populations by genes of hereditary diseases is generally small, since mutations that give rise to hereditary diseases reduce the adaptability of patients regardless of their ethnic or geographical origin. However, mutations can also lead to positive effects, such as the emergence of resistance to diseases. The occurrence rate of such an acquired property is equal to 2 % of mutation cases [16, 17].

In the prevalence of hereditary diseases, the role of gene drift and the founder effect explains perfectly the accumulation of some forms of hereditary pathology in individual populations. There are more than 20 hereditary diseases (mainly autosomal recessive) in the population living on the Scandinavian Peninsula, the frequency of which is significantly higher than in any other populations. The phenomenon of accumulation of hereditary diseases in this area is associated with the effective drift, long-term genetic isolation, and a high inbreeding coefficient [18]. At least two dozen diseases that occur with high frequency have been described in some European residents [19].

The general structures of the genetic diversity of modern man were formed during settlement under the effect of migrations, gene drift, and abrupt changes in the effective population size. The role of natural selection for individual parts of the genome is insignificant both in the formation of genetic diversity on a global scale (for example, by genes of immune response or skin pigmentation) and in the adaptation of a population to local environmental conditions (for example, by genes of metabolism of substances coming from food).

In gene pools, the transformation of a population proceeds under the influence of a complex of evolutionary factors. Natural selection is important, as well as the pressure of mutations. If a particular allele is supported by natural selection, then the carriers of this allele (as the most adaptive) are characterized by preferred reproduction. Selection displaces all other alleles without exception. Natural selection in the human population functions equally against both homozygotes (dominant and recessive) and heterozygotes.

The human population in ECH will be devoid not only of natural selection but also of other evolutionary factors – mutation process, migrations, gene drift. In order to prevent the accumulation of the above and other hereditary diseases in an enclosed population, it is necessary to support the change of the gene pool at the expense of the genetic bank.

Program of Genetic Movement of the Population

It is important that the population movement does not stop. Accordingly, it is necessary to create a bank of genetic material that will solve a number of problems arising from the influx and outflow of genetic information in the human population. This approach is conditioned by the following reason: according to the genetic calculations carried out

on the basis of 16 individuals (the first generation), of which eight are female, eight are male, when crossbreeding with each other, as a result, a single representative remains by the fifth generation (Figure 3).

Figure 4 shows that in case of crossbreeding of two parents carrying the albinism gene, there occurs a standard segregation according to the genotype described in Mendel's second law. However, in case of crossbreeding of two parents, one of whom is a carrier of the gene, and the other is healthy, we observe how the generation tends to accumulate homozygous traits. It is important to clarify that albinism is inherited by an autosomal recessive type of inheritance.

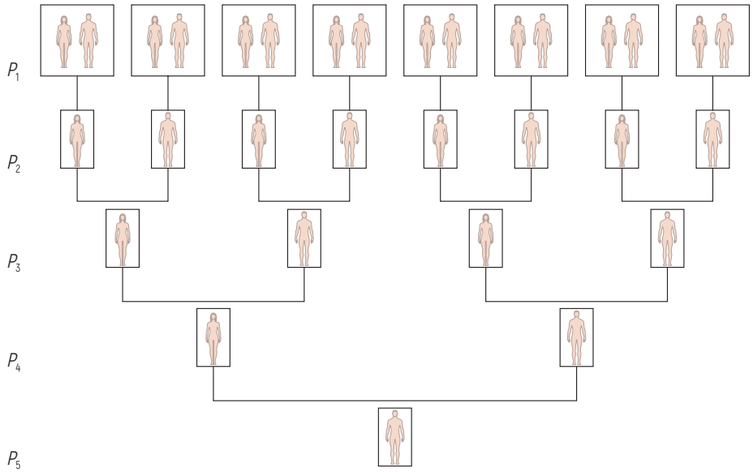

Figure 3 – Diagram showing the problem of the human population in an enclosed ecosystem:
P – parents (P_1, P_2, P_3, etc.)

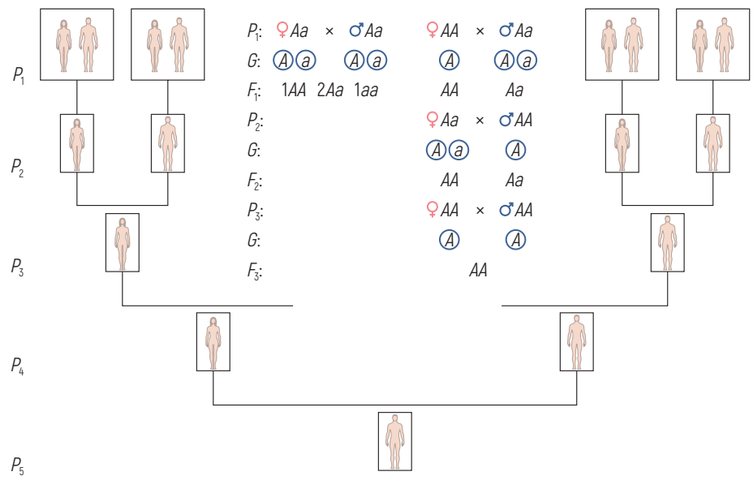

Figure 4 – Diagram showing a trait inherited in autosomes:
A – normal skin pigment (dominant trait); *a* – albinism (recessive trait);
P – parents (P_1, P_2, P_3, etc.); *F* – generation (F_1, F_2, F_3, etc.); *G* – gametes

Based on the above calculations, the following can be stated: by the hundredth generation, genetic material will be mixed, which will lead to the accumulation of homozygous traits among the ECH population.

The selection of genetic material (spermatozoa and oocytes – progenitor cells of human haploid germ cells) and its cryopreservation will help to avoid closely related crossbreeding in the first and subsequent generations and support the trend of the heterozygous state of the population.

Totipotent stem cells will be immediately taken from the first generation settled in ECH and transferred to the ECH genetic bank (Figure 5).

The genebank will start operating from the second generation, which will also have the selection of genetic material for cryopreservation and the use of cells in artificial insemination of the hundredth generation living in ECH.

Mankind uses genetic banks for artificial insemination in the treatment of male and female sterility [20]. The availability of repositories of genetic material will help to avoid hereditary diseases, gene drift, adaptation, struggle for existence, variability, and other evolutionary factors.

The material taken from the first inhabitants of ECH will be used only after the hundredth generation to obtain the most diverse genotypes within the population

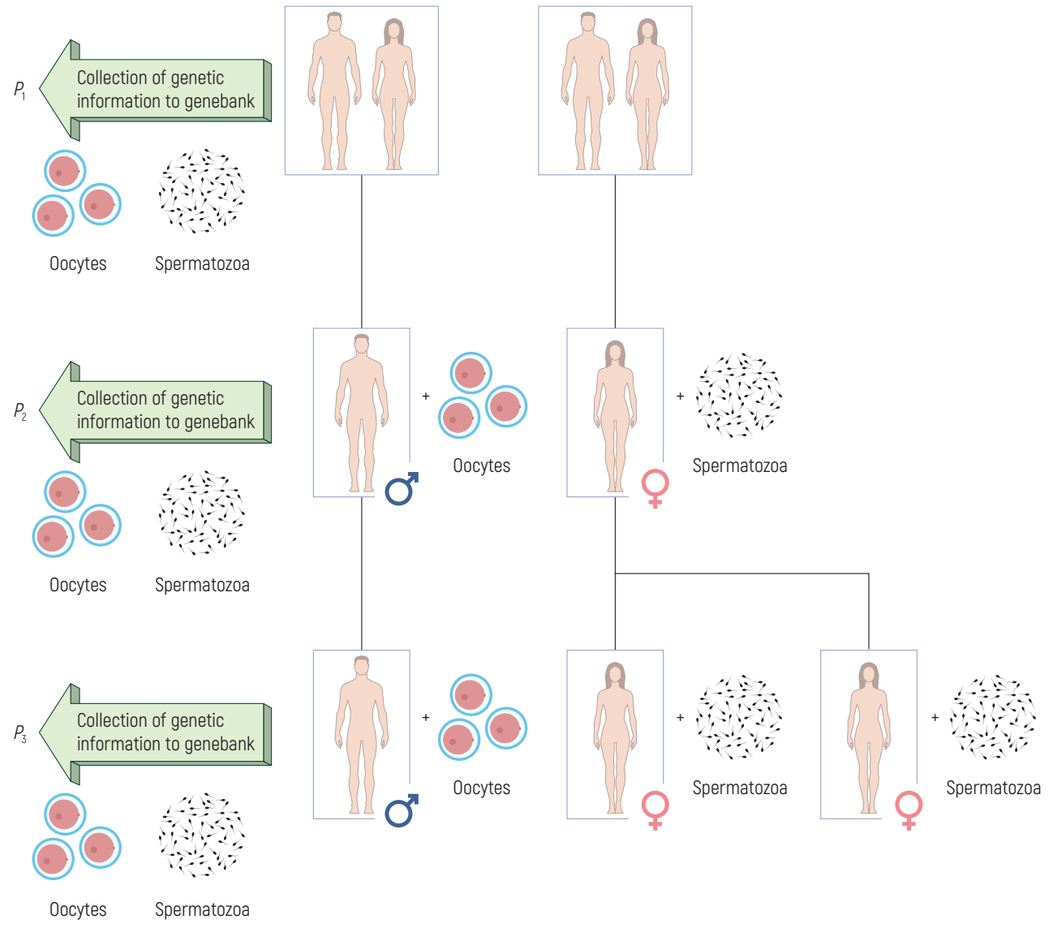

Figure 5 – Role of the genebank of human hereditary information in an enclosed ecosystem:
P – parents (P_1, P_2, P_3, etc.)

of the enclosed ecosystem. Up to the hundredth generation, it is planned to use pre-readied genetic material stored in the ECH genebank, taken from various human populations on the planet Earth.

Each subsequent generation of ECH, starting from the second, should use the genetic bank as a source of creating healthy and progressive offspring, as well as contribute their own totipotent stem cells to replenish the genetic diversity of the bank.

According to the cryopreservation methods, during rapid freezing of egg cells (vitrification of oocytes), unlike slow freezing, ice crystals cannot form on the surface and inside the egg cells. As a result, this genetic material (98 %) retains its vital properties.

The term of reservation of egg cells in frozen form does not have a negative impact on their viability. Damage can only occur at the freezing or defrosting stage. The recommended period of egg cell freezing is 5–7 years.

The exact period of preserving the viability of spermatozoa has not yet been clarified. To date, the longest period of its cryopreservation is 21 years. When using such spermatozoa, successful fertilization of the egg cell followed by a healthy pregnancy was observed [21].

Conclusions and Future Work

As a result of the analysis of scientific researches, the probability of occurrence of homozygous movement of the human population in ECH was comprehensively assessed.

The biological effect of individual mutations or polymorphisms on the disease is usually stable and does not depend on the racial, ethnic, or geographical context. At the same time, the strength of the effect, i.e., the relative contribution of the marker to the disease or the risk of its development, can vary significantly at the population and individual levels due to different genetic (haplotypic) environment, modifying "gene – gene" and "gene – environment" interactions.

Consequently, the appearance of mutations during natural selection is inevitable if new genetic information does not enter the population. This is important for the evolutionarily stable development of all populations without exception, including animals and plants. Based on the above, a proposal has been made to create a human genebank; such an approach will solve problems with genetic information. To create a genebank, it is proposed to select genetic material and perform its cryopreservation, which is necessary

in order to maintain an infinitely long human existence in an enclosed ECH ecosystem.

In subsequent studies, the generated scheme of the movement of genetic information in an enclosed ECH population will be improved for further implementation and inclusion in a large-scale project to create ECH, which will ensure a stable life for both humans and all representatives of the vertebrate fauna of the planet. It is planned to apply a dual method of preserving genetic information to plants – cryonics of callus tissues and conservation of haploid germ cells. In addition, the researches will be aimed at solving issues related to the storage of genetic information in enclosed populations, as well as affecting the necessary exchange and ways of introducing the genebank into enclosed ecosystems.

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UDC 641.1/3

Development of All-Inclusive Diet for the EcoCosmoHouse Residents

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The issue of providing a full and varied nutrition to the residents of an enclosed ecosystem – EcoCosmoHouse (ECH) is considered in this report. The features of diets in enclosed ecosystems, prevention of metabolic syndrome, ways to exlude problems associated with lactose intolerance, celiac disease are considered. A universal menu has been proposed for the ECH residents. It meets the general requirements for a healthy diet and the peculiarities of nutrition in enclosed ecosystems. The food complex is selected in such a way as to simplify as much as possible the arrangement of an enclosed biotechnological cycle, which assumes complete waste processing, in addition to obtaining high-quality bioproducts. Living organisms of high-performance are proposed as food sources in ECH.
The purpose of this research is the theoretical selection of an optimal set of products that can be manufactured in an enclosed ecosystem with minimal resource costs.
The novelty and uniqueness of this issue is due to the fact that the diet compiled by the authors is suitable for the widest possible range of people, including those suffering from metabolic syndrome, lactose intolerance, celiac disease.

Keywords:
diet, bioproduction, vitamins, enclosed ecosystem, macroelements, microelements, metabolic syndrome, lactose intolerance, celiac disease, EcoCosmoHouse (ECH).

Introduction

EcoCosmoHouse (ECH) is an integral part of the residential and industrial infrastructure of the orbital industrial complex – the Industrial Space Necklace "Orbit" (ISN "Orbit"). At the same time, it is, in fact, an enclosed ecosystem in which all residents should be provided with a balanced, complete nutrition [1].

A healthy diet is a nutrition that ensures the growth, normal development, and vital activity of a person, contributes to strengthening of his health and the prevention of diseases [2, 3]. The basis of composing any diet is such a thing as a balance of macro- and micronutrients, i.e., food must also meet the needs of the human body for the necessary ultra-, macro-, microelements and biologically active substances, rather than just have sufficient calories [4–6].

The nutrition of the ECH residents should provide the following:

- obtaining a complete set of macro- and micronutrients;
- achievement of energy balance and a normal weight;
- limitation of saturated fats (up to 30 % or less of the total energy consumption), their replacement with unsaturated fats (90 % or more);
- consumption of the optimal amount of fruits and vegetables, as well as beans, whole grains, and nuts (at least 400 g of fresh fruits and vegetables per day);
- reduction of free sugars intake to 10 % or less of the total energy consumption;
- reduction of salt (sodium) intake to 5 g or less per day; its partial replacement with potassium salts (potassium chloride) [7].

Despite the limited space for bioproduction of products, the menu of the ECH residents should be as close as possible to the terrestrial one. At the same time, when compiling it, it is important to take into account the peculiarities of diets in an enclosed ecosystem. The product range should also be diverse, but not excessive, i.e., using the minimum number of food sources, it is necessary to get the maximum benefit and the best taste qualities.

When developing the diet for the ECH residents, it is necessary to provide for the ease of disposal of the resulting organic residues and strive to minimize their volume.

The correct selection of nutrition in ECH is an extremely important issue that determines the health, wellbeing, efficiency, and long life of people [8].

Prevention of Metabolic Syndrome, Exclusion of Problems Associated with Lactose Intolerance, Celiac Disease

When drawing up a balanced menu for the ECH residents, it is necessary to proceed from the most common cases of health disorders arising from improper nutrition on Earth. Despite the versatility of the recommendations, everyone living in ECH should know which food is preferable for him in order to prevent possible allergic reactions and adjust his diet accordingly [9].

Some of the most common nutritional ailments are metabolic syndrome, lactose intolerance, and celiac disease. Efforts should be concentrated on preventing these problems that directly affect the well-being and health of a person.

Metabolic syndrome is a complex of phenomena that includes abdominal obesity, impaired carbohydrate metabolism, dyslipidemia, and arterial hypertension. It occurs on average in 10–20 % of the population of developed countries [10].

Non-drug methods are considered to be the best prevention of this disease, in particular, the reduction of total caloric content of foods while preserving all macro- and micronutrients important for health and increasing physical activity [11]. As part of the diet, it is necessary to reduce the proportion of saturated fatty acids and increase the proportion of unsaturated ones [12, 13].

In addition, herbal preparations with hypoglycemic, hypolipidemic, and hypotensive effects are planned to be used for the treatment and prevention of the occurrence of metabolic syndrome. They will include ginger root, aronia fruits, cinnamon rosehip fruits, common bean leaves, white mulberry leaves, medicinal galega grass, black currant leaves, Chinese lemongrass fruits, creeping thyme grass, medicinal sage leaves, nettle leaves [14–16].

The proposed diet for the ECH residents has been adjusted to increase the proportion of polyunsaturated fatty acids, which also helps to prevent the development of metabolic syndrome.

Lactose intolerance manifests itself in bloating, diarrhea, nausea, and other symptoms that occur when consuming dairy products containing lactose. The problem of lactose intolerance (about 20 % of the population suffer on average) is proposed to be solved under the ECH conditions by replacing dairy products with their vegetable analogues – vegetable milk and soy cheese [17]. Vegetable, or lean, milk is not a 100 % substitute for regular milk, but it is not inferior to it in many features. Its production obviously does not require breeding of dairy animals. Keeping and caring for such animals is a labor-intensive technology, whereas vegetable milk is produced in a significant volume without high costs due to the use of relatively simple equipment (in most cases heating and grinding equipment is sufficient) [18]. At the same time, there are no people who need milk vitally. Its use is a matter of taste preferences. In general, with the further development of this subject area, animal milk and dairy products (including fermented and lactose-free ones) can be added to the diet of the ECH residents, but considering the above, it seems more appropriate to replace dairy products with their vegetable analogues at this stage.

Currently, many types of vegetable milk are offered:

- oatmeal, rice, corn, spelt (raw materials – cereals);
- soy, peanut, lupine, from cowpea and mukuna (raw materials – leguminous);
- almond, coconut, pistachio, pine, walnut, and hazelnut (raw materials – nuts);
- sesame, flax, hemp, sunflower (raw materials – oilseeds);
- amaranth, quinoa, teff grass (raw materials – pseudocereals crops).

A wide variety of the initial product used for the preparation of lean milk will allow everyone to choose for themselves the most suitable to taste [19].

Another important problem of modern nutrition is celiac disease, which affects 0.2–6 % of the population in various regions of the world in one form or another [20]. Celiac disease is caused by gliadin – one of the gluten fractions contained in the gluten of cereals (wheat, barley, rye). This disease occurs in a person genetically predisposed to it, and is characterized by atrophy of the villi of the mucous membrane

of the small intestine, as a result of which symptoms such as abdominal pain, nausea, diarrhea appear [21].

To prevent the development of celiac disease, wheat, barley, and rye should be excluded from the diet of people prone to it, replacing them with buckwheat, millet, quinoa, and other grain or pseudocereals crops. The value of nutrition will not decrease from this; the disadvantages of such a gluten-free diet can only be related to taste preferences [22, 23].

Features of Food Ration in an Enclosed Ecosystem

In ECH (despite the fact that it is a space object), it is planned to reproduce living conditions much closer to those on Earth than the conditions in the existing spacecraft. ECH is supposed to implement the most favorable climate and create an analogue of gravity. Such a solution will provide residents with complete nutrition obtained directly inside the enclosed biosphere. In this case, there will also be no dietary restrictions that are inherent in the astronauts' menu (for example, it will not be necessary to use special preparations instead of natural calcium sources to make up for the deficiency in it or limit the size of loaves of bread to "one bite" to prevent crumbs from flying away) [24].

It is worth considering some norms of nutrition of astronauts in cases where they are applicable. Such a mandatory criterion is a sufficient amount of nutrients. Astronauts should be provided with them in accordance with the needs of the body that arise at different stages of a space flight. The living and work conditions during the flight are extreme, therefore, the lack of important nutrients is unacceptable [25].

Astronauts on the ISS are provided with food for approximately two weeks. Their diet consists of the main and additional parts. The main share is combined both from food specially made for astronauts and from industrial products that have passed certain tests.

In ECH, food supplies from outside are not expected, as is the formation of such food packages. Its inhabitants should take healthy and nutritious meals in their usual form, despite the fact that the enclosed ecosystem itself is located in space.

Food Sources in ECH and Waste Disposal

For the bioproduction of plant-based and animal-source food, it is planned to use technologies that allow obtaining the maximum amount of products from 1 m^3 of spacing.

An important factor in this case is the amount of oxygen produced by plants and its consumption by animals, which should be considered when calculating the entire system [26, 27].

The main technologies that will be used for growing plants are the application of light potting soils and humusoponics (aeroponics based on liquid humus) [28–31]. Light potting soils and nutrient solutions for humus must have a sufficient content of mineral components and organic matter of humus. It contains 86 elements found in the human body, so plants will receive a full set of ultra-, macro- and microelements from it in the form of salts of organic compounds, which will then be used by other living organisms in ECH.

The source of animal food will be animals that provide the maximum amount of food raw materials, are unpretentious in care and relatively small in size (for example, guinea pigs or rabbits) [32].

An important component of nutrition is water. In the human body, it usually makes up to 75 % of body weight and performs many functions. On average, at least 1.5–2 l of it should be consumed per day. The quality of the water used largely determines a person's health: he receives with it many ultra- and microelements [33]. It is proposed to enrich the water in ECH with microelements, passing it through minerals, which will attribute it a therapeutic effect [34].

It is planned to replace the edible salt in ECH with dried halophyte plants: soleros, salt orache. These cultures not only replace ordinary salt but are also considered as sources of valuable biologically active substances [35].

In order to return useful elements to the ecosystem, a waste disposal cycle will be arranged under the ECH conditions. It includes a stage of processing that goes on with the participation of macro- and microorganisms and is similar to what is observed in wildlife. This is a highly efficient process with the additional use of earthworms, fly larvae, and other small animals. To obtain humus from organic waste, processing with the help of anaerobic microorganisms will also be applied. They do not need oxygen during their vital activity and, accordingly, do not absorb it from the atmosphere. As a result a fertile humus is created, containing all the elements necessary for living organisms. Water, like other food components, is not planned to be delivered to ECH separately: it will be returned to the ecosystem from organic waste and wastewater during their natural microbiological processing in the soil.

Some waste, such as plant residues, should be processed not into humus, but into compost suitable for growing cellulose-destroying mushrooms (oyster mushrooms, shiitake, etc.) [36].

Household chemicals should be completely replaced in ECH with plant-based eco-friendly analogues, since the current scientific and technical level of development in eco-production allows it to be carried out in full. With the use of eco-friendly chemicals and other substances, their negative impact on soil microorganisms and humans will be excluded [37].

All-Inclusive Diet for the EcoCosmoHouse residents

The all-inclusive diet for the ECH residents, theoretically developed taking into account the requirements outlined above, is presented in the Table below.

We can get a varied menu by combining these products and using different cooking methods.

Table – All-inclusive diet for the ECH residents

Food product	Weight, g	Calorific value, kcal/100 g	Calorific value, kcal	Useful nutrients
1	2	3	4	5
Quail meat	100	134	134	Essential amino acids, monounsaturated and polyunsaturated fatty acids, zinc, chromium, iron, phosphorus, potassium
Guinea pig meat	100	156	156	Essential amino acids, vitamins PP, B_2, calcium, chromium, sodium, magnesium, potassium, iron, phosphorus
Quail eggs (used with shell)	90	155	139.5	Vitamins A, B_1, B_2, PP, micro- and macroelements (calcium, iron, phosphorus, potassium, cobalt, copper), essential amino acids (threonine, tyrosine, glycine, lysocine, and histidine)
Mushrooms (oyster mushroom, shiitake)	200	34	68	Amino acids, microelements, vitamin D, enzymes (amylase, lipase, urease, citase, etc.) that facilitate the breakdown of fats, fiber, glycogen
Trout	150	97	145.5	Essential amino acids, vitamins B_1, B_2, B_5, B_{12}, D, PP, choline, potassium, phosphorus, manganese, copper, selenium
Shrimps	50	55	27.5	Essential amino acids, vitamins B_{12}, D, zinc, copper, manganese
Wheat flour	75	342	256.5	Polysaccharides, dietary fiber, magnesium, vitamins E, B_1, B_2, B_5, folic acid, calcium, phosphorus, zinc, copper, iron, manganese
Buckwheat flour	75	329	246.8	Polysaccharides, dietary fiber, magnesium, vitamins B_1, B_6, PP, silicon, phosphorus, iron, cobalt, manganese, copper
Potatoes	450	77	346.5	Polysaccharides, vitamins C, B_6, potassium, magnesium, zinc, phosphorus
Chufa (ground almonds)	40	609	243.6	B vitamins, as well as vitamins A, C, E, copper, iodine, selenium, potassium, sodium, zinc
Tofu cheese (soy)	50	70	35	Amino acids, vitamins B_1, B_2, B_3, B_4, potassium, calcium, magnesium, phosphorus
Tomatoes	150	20	30	Lycopene, fiber, vitamins A, C, B_1, B_2, potassium
Cabbage	100	25	25	Dietary fiber, vitamins A, B_1, B_6, C, potassium, phosphorus, cobalt, copper, zinc, magnesium
Onion	20	50	10	Vitamins C, E, K, beta-carotene, silicon, cobalt, manganese
Apples	200	47	94	Simple carbohydrates, pectin, biotin, vitamins A, C, B_1, B_2, PP, E, potassium, magnesium, phosphorus, iodine, iron
Grape	120	72	86.4	Simple carbohydrates, anthocyanins, vitamins C, A, B_2, B_9, beta-carotene, potassium, phosphorus
Radish	50	16	8	Vitamin C, cobalt, copper, molybdenum, chromium
Sunflower microgreens	100	62	62	Polyunsaturated Omega-3 and Omega-6 fatty acids, interchangeable and essential amino acids, vitamins B_1, B_5, B_6, B_9, E, nicotinic acid
Microgreens of peas	50	124	62	Polyunsaturated Omega-3 and Omega-6 fatty acids, vitamins B_1, B_5, B_6, B_9, C, PP, potassium, magnesium, phosphorus, iron
Lettuce	50	12	6	Dietary fiber, vitamins B_1, B_9, iron, calcium, magnesium, potassium
Ruccola	50	25	12.5	Dietary fiber, vitamins A, B_9, C, K, beta-carotene, potassium, calcium, magnesium, manganese
Honey	25	329	82.3	Simple carbohydrates, B vitamins, as well as vitamins K, E, C, magnesium, potassium, sulfur, zinc, iodine, copper
Kombucha (drink)	200	32	64	B vitamins, organic acids, amino acids, enzymes, polyphenols
Vegetable milk	200	45	90	Biologically active substances, microelements, vitamins depending on raw materials (soy, wheat, oats, etc.)
Medicinal and spicy herbs	10	20	2	Biologically active substances, microelements, vitamins, depending on the type of grass
Chlorella	20	1	0	B vitamins, as well as vitamins K, E, C, beta-carotene, folic acid, choline, niacin, flavonoids, glycoproteins, calcium, sulfur, iodine, dietary fiber, silicon, chromium
Total	Total weight*, g	Average calorific value, kcal/100 g	Total calorific value, kcal	All macro- and micronutrients necessary for life
	2,725	113	2,433.1	

* The weight of products is indicated in raw condition, while 420 g of this diet are drinks. The total weight of food after cooking and excluding drinks will be 1.3–1.5 kg.

Conclusion

Thus, the above theoretically developed all-inclusive food complex for the ECH residents meets the general criteria for a healthy diet and dietary requirements in an enclosed ecosystem. Such a menu prevents the development of metabolic syndrome, celiac disease and is suitable for people with lactose intolerance, while providing a wide variety of food flavors and a full set of macro- and micronutrients. The bioproduction of these products requires minimal resources under the ECH conditions, and all waste generated can be converted with the help of macro- and microorganisms into humus used for growing cultivated plants.

In the future, it is planned to conduct a more detailed theoretical study of the complex menu, analyze the options for specific dishes and carry out practical testing of the diet under terrestrial conditions.

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UDC 635.8

Medicinal and Edible Mushrooms in an Enclosed Ecosystem: Cultivation, Properties, Application

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The useful properties of medicinal and edible mushrooms, such as reishi (*Ganoderma lucidum*), shiitake (*Lentinus edodes*), oyster mushroom (*Pleurotus ostreatus*), and lion's mane (*Hericium erinaceus*) are considered; their impact on the human body under the conditions of an enclosed ecosystem is assessed. Methods for extensive and intensive cultivation of mushrooms, including the use of fallen leaves, wood, and other organic materials as a substrate, have been proposed. The use of mushrooms (as a source of nutrients and immunomodulators) in the diet of the EcoCosmoHouse (ECH) residents is justified. The scheme of the experiment on mushroom cultivation in the conditions of ECH is proposed.

Keywords:
mushrooms, reishi, shiitake, oyster mushroom, lion's mane, extensive cultivation, intensive cultivation, medicinal mushrooms, edible mushrooms.

Introduction

Mushrooms are an independent kingdom of living organisms. The higher basidiomycetes include mushrooms with macroscopic bodies numbering about 10,000 species. Higher edible basidiomycetes are representatives of different ecological groups, mainly mycorrhizophores, saprotrophs, lignotrophs, and coprotrophs.

A large proportion of mushrooms traditionally eaten belong to the higher basidiomycetes. Edibility is a category that encompasses notions of palatability, physiological, and aesthetic acceptability. This property of the species reflects the genetically fixed features of the chemical composition and morphology of the mycothallus.

The range of mushrooms eaten in different regions depends on the choices available, traditions, and tastes of the people [1].

The world of edible mushrooms includes 200–500 species, but no more than 20–50 are widely used for food purposes [2]; about 10 are used commercially [3].

Almost all edible basidiomycetes have rare or unusual amino acids [2]. Their presence has been found to be responsible for the specific taste of mushrooms [1, 4], while the odor is formed by other compounds [5].

In addition to amino acids, edible mushrooms contain polysaccharides that have antimicrobial, antioxidant, anticancer, and other properties [6] (Table 1). Basidiomycetes also contain dietary fibers with antioxidant effects [7].

Table 1 – Medicinal properties of mushrooms

Mushroom	Action taken on the organism						References
	Antiviral	Antimicrobial	Antioxidant	Antineoplastic	Immunomodulatory	Cognitive functions, CNS	
Reishi (*Ganoderma lucidum*)	+	+	+	+	+	+	[8–19]
Shiitake (*Lentinus edodes*)	+	+	+	+	+	+	[20–30]
Lion's mane (*Hericium erinaceus*)	+	+	+	+	+	+	[31–48]
Oyster mushroom (*Pleurotus ostreatus*)	+	+	+	+	+	+	[22, 49–61]

Mushrooms are a rich source of digestible protein (Table 2), as well as essential fats and carbohydrates (Table 3) [62].

Table 2 – Comparison of the biological value of protein in different foodstuffs

Product	Biological value of protein, cond. units
Milk	100
Fish	85
Mushrooms	82
Meat	80
Beans	50–55
Cereal	40–45

Table 3 – Content of nutritional components in mushrooms (calculation per dry substance)

Component	Content, %
Protein	12–35
Carbohydrates	4–6
Fats	0.4–0.6
Fibers	1
Ash	11

Minerals such as calcium, phosphorus, and iron in oyster mushrooms are twice as high as in pork and beef. The high potassium content and low sodium content (K : N = 100 : 1) are beneficial for hypertensive people.

For vegans, mushrooms are the only supplier of calcium. The selenium in mushrooms acts as an antioxidant and helps to fight viral infections.

Carbohydrates in mushrooms are only 4–6 %. These biological bodies are practically not digested in the human gastrointestinal tract, so there is no decomposition to glucose and no change in the glycemic level in the blood. This makes mushrooms indispensable in the diet of people with diabetes mellitus.

Mushrooms contain all water-soluble vitamins, including vitamin C and group B. For example, vitamin B_3 in oyster mushrooms is 5–10 times more than in vegetables [2, 62].

All of the above makes mushrooms a dietary and delicacy product that is obtained on an industrial scale.

The purpose of this article is to analyze scientific sources presenting the properties, cultivation methods, characteristics, and variants of application of medicinal and edible mushrooms (reishi, shiitake, lion's mane, oyster mushroom), as well as methods of developing extensive and intensive technologies for their cultivation.

World Mushroom Production

The global mushroom market is conventionally divided into three sectors: edible, medicinal, and wild (harvested in nature). Altogether, this industry was valued at 63 bln USD in 2013. The production of edible and medicinal mushrooms was valued at 34 bln USD and 24 bln USD respectively.

Between 1978 and 2013, mushroom cultivation increased more than 30-fold, from 1 mln tons to 34 mln tons (Figure 1). It is worth noting that the main supplier, China, accounts for 87 % of the mushroom market.

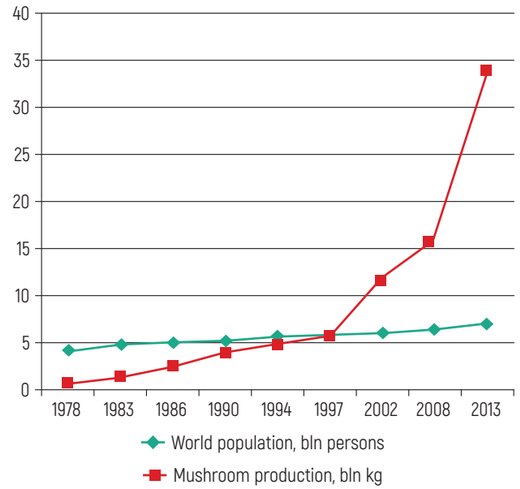

Figure 1 – Global edible mushroom production market [63]

Lentinus species (22 % of the market) and oyster mushrooms (19 %) are the most industrially cultivated. However, medicinal mushrooms such as lion's mane and reishi are much less common [63].

Brief History of Mushrooms and Their Distribution

Shiitake (*Lentinus edodes*), or shitake, black mushroom, lentinus edible, is one of the oldest mushroom cultivars. Mention of it is found in ancient manuscripts, which are thousands of years old. The mushroom is still revered in Japan and China as an elixir of life. The famous healer Wu Shu (14th–17th centuries) wrote in a medical treatise that shiitake gave people cheerfulness and provided energy, was a preventive remedy against stroke [64].

Under natural conditions, the mushroom is widespread in East and South-East Asia. It is found sporadically in the Far East in Russia. It grows only on the dead wood of various species of oak and hornbeam, chestnut and beech, as well as on other deciduous trees of the above regions (Figure 2). The mushroom has not been found in Belarus.

Figure 2 – Shiitake growth on different substrates

Reishi (*Ganoderma lucidum*), or lingzhi, ganoderma lucidum, the mushroom of immortality, has been considered a medicinal mushroom for about 2,000 years [65, 66]. It is found worldwide in temperate and subtropical areas, including North and South America, Europe and Asia [67]. A general view of the fruiting body is shown in Figure 3.

Figure 3 – Mycothallus of reishi

Lion's mane (*Hericium erinaceus*), or houtougu, yamabushitake, monkey head, grows on both living and dead wood [68]. Lion's mane (Figure 4) is also found in Europe, in addition to Asian regions, but is listed in the Red Data Book of 13 European countries due to its poor germination [69].

Figure 4 – Mycothallus of the lion's mane [70]

The oyster mushroom (*Pleurotus ostreatus*), or oyster cap, is common in Belarus. The mushroom has been extensively cultivated for several centuries [71].

Technologies for the Cultivation of Mushrooms

There are two basic technologies for producing mushrooms: extensive (under ambient conditions, including on wooden logs or sticks) and intensive (in specially equipped premises where it is possible to cultivate mushrooms on certain substrates all year round: straw, sawdust, compost, etc.).

Extensive plantation cultivation of mushrooms, namely cultivation on wooden logs, is a simple, reliable, and low-cost technology. According to the literature, the most commonly used methods of infestation with the mushroom inoculum are soil, disc, and inter-billet inoculation.

Soil method. In the spring or early summer, individual holes 15–25 cm deep are dug on the plot according to the diameter of each log. The distance between the holes should be at least 20 cm from the edge to allow the mushrooms to grow. The bottom of the holes should be irrigated or sprinkled with wet sawdust. The latter are tamped down. Then the fungus is scattered over the bottom of the hole, onto which the log is placed end-to-end (Figure 5).

The log should be dug in, somewhat compacting the soil around it. During the first period (especially when the weather is dry and hot), the soil around the log should be watered at least once a week. When inoculating the logs with the soil method, the oyster fungus penetrates into the soil, where it forms ground mycelium, which actively develops and receives additional nutrients. This method allows the substrate to germinate abundantly with mycelium and increases the mushroom yield.

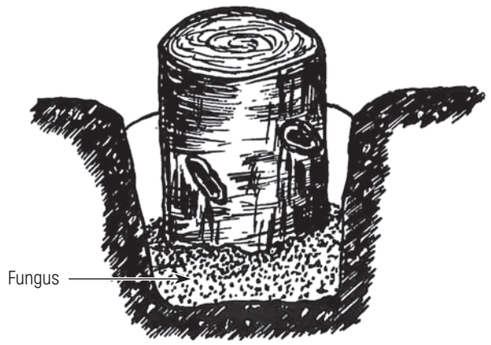

Figure 5 – Soil infestation of logs with fungus [71]

Disc method. A disc 3–4 cm thick (depending on the diameter) should be sawn from each log. A 1–2 cm thick layer of fungus should be placed on the top end surface of the log; then the sawn disc should be nailed to keep it from moving (Figure 6). Alternatively, 4–6 holes 1–2 cm in diameter and up to 10 cm deep can be drilled in the bottom of the log, which are filled with the fungus. The infested logs should then be planted in the prepared holes in a permanent location, like in the soil method of infestation.

To protect the mycelium from the wind, a plastic bag can be placed over the wooden deck and tied with a string.

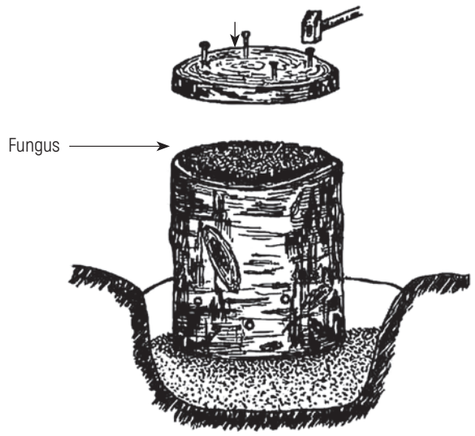

Figure 6 – Disk infestation of logs with fungus [71]

Inter-billet method. A trench at least 1 m deep should be dug (this is necessary to maintain a special microclimate in the cavity). A small layer of damp sawdust is placed at the bottom and some fungi are placed on top. Then the logs are stacked upright on top of each other in several rows (Figure 7) to form columns 1.5–2 m high.

Preferably, the wooden stakes should be approximately the same diameter. Under each log and between the ends, a 1–2 cm layer of fungus should be placed along the length of the logs. To prevent the mycelium from drying out, the logs should be covered with clean, dry straw.

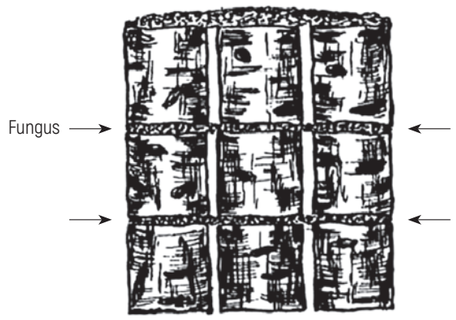

Figure 7 – Inter-billet infestation of logs with fungus [71]

The logs should be placed permanently in the soil to a depth of 1/2 their length; the gaps in the row and between the rows should be 20–30 cm (Figure 8).

Figure 8 – General view of the mushroom plantation

Once planted, the logs should not be moved. In the first year, 50 g to 600 g of mushrooms, sometimes up to 1 kg, are harvested from a single log. However, it may happen that they will not appear in the first season because the fungus has not yet matured enough to form mycothallus or a frost has set in early. The following year (under favorable weather conditions), up to 2–3 kg of mushrooms will grow on each log left to overwinter in the same place. The second and third periods of fruiting bring the highest yield. The total oyster yield is 70–100 kg per 1 m^3 of soft wood [71].

Using intensive technology, mushrooms are grown on an industrial scale in a strictly controlled environment – in a special room with a certain temperature and humidity. The mushrooms are usually grown in bags or jars filled with the necessary substrate. Some authors argue [72] that growing mushrooms in bags gives a higher biomass yield, which is correspondingly more cost-effective. Thus, 5 kg of raw material allows to obtain 1 kg of mushrooms.

Most often, waste from the wood processing industry and agriculture is used: sawdust, straw, and plant matter after spinning. Depending on the type of mushroom being cultivated, gypsum, soybean meal, and mineral salts are sometimes added to create a certain value of active acidity [72, 73].

The composition of the nutrient medium directly affects the productivity of the mushroom and its biomass yield [73]. Consequently, in order to develop an intensive technology, the components of the nutrient medium are selected experimentally, taking into account the characteristics of the local raw material (Table 4).

Table 4 – Influence of nutrient media components on mushroom biomass yield [73]

Substrate	Type of mushroom	Yield, kg/10 kg moist substrate
Banana leaves	*Pleurotus quebeca*	1.2
Bean straw	*P. pulmonarius*	2.6
Bean straw	*P. cornucopiae*	2.25
Corn cobs	*P. hybridus*	2.7
Corn cobs	*P. citrinopileatus*	1.9
Cotton straw	*Collybia velutipes*	1.54
Flax peel	*P. hybridus*	2.42
Gram flour	*Stropharia rugosa annulata*	3.4
Composted horse manure	*Agaricus bisporus*	2.8
Composted horse manure	*Lapiota naucina*	1.45
Oil palm pericarp	*P. hybridus*	1.94
Peanut shell	*P. sajor-caju*	0.97
Rice straw	*P. citrinopileatus*	2.4
Sawdust (enriched with bran)	*C. velutipes*	2.62
	Lentinus edodes	1.91
Shredded paper	*P. hybridus*	0.38
Sorghum straw	*P. sajor-caju*	1.6
Sugar cane oilcake	*P. hybridus*	2.3
Bark of a tree	*P. sajor-caju*	0.97

Cultivating Mushrooms in an Enclosed Ecosystem

Solid residues of plant biomass, as well as waste products from livestock animals, can be used as a basis for cost-effective cultivation, which is particularly relevant in an enclosed ecosystem (Figure 9) [74, 75]; reishi has been successfully grown under similar conditions [76].

Enrichment of Mushrooms with Biologically Active Components

It is known that long periods of confinement lead to psychological discomfort. More often than not, the person starts to show aggressive behavior or suicidal tendencies. Such disorders are treated with lithium preparations.

To increase the bioavailability of lithium or other elements (Ca, K, Mg, Na) they can be added to the nutrient medium in which the mushroom is cultivated [77].

Oyster mushroom and reishi have been enriched with the necessary chemical elements [78].

In this way, the biomass of the mushroom will contain biologically active components that are important for the normal functioning of people living in EcoCosmoHouses (ECH). For example, it is enough to eat 100 g of lithium-saturated lion's mane to get 69 % of the daily dose of the element [77]. In addition, mushrooms can be added to minced meat when meat is scarce, i.e., when there is a lack of protein in people's diets [4].

Materials and Methods

The first step in any mushroom cultivation method is to obtain seed. To solve this problem, the authors of the study purchased a minimum quantity of mushroom mycelium (reishi, shiitake, lion's mane, and oyster mushroom) to multiply it under laboratory conditions in order to simulate a situation in which four 50-gram sachets of seed are delivered to ECH (to save space and transportation costs).

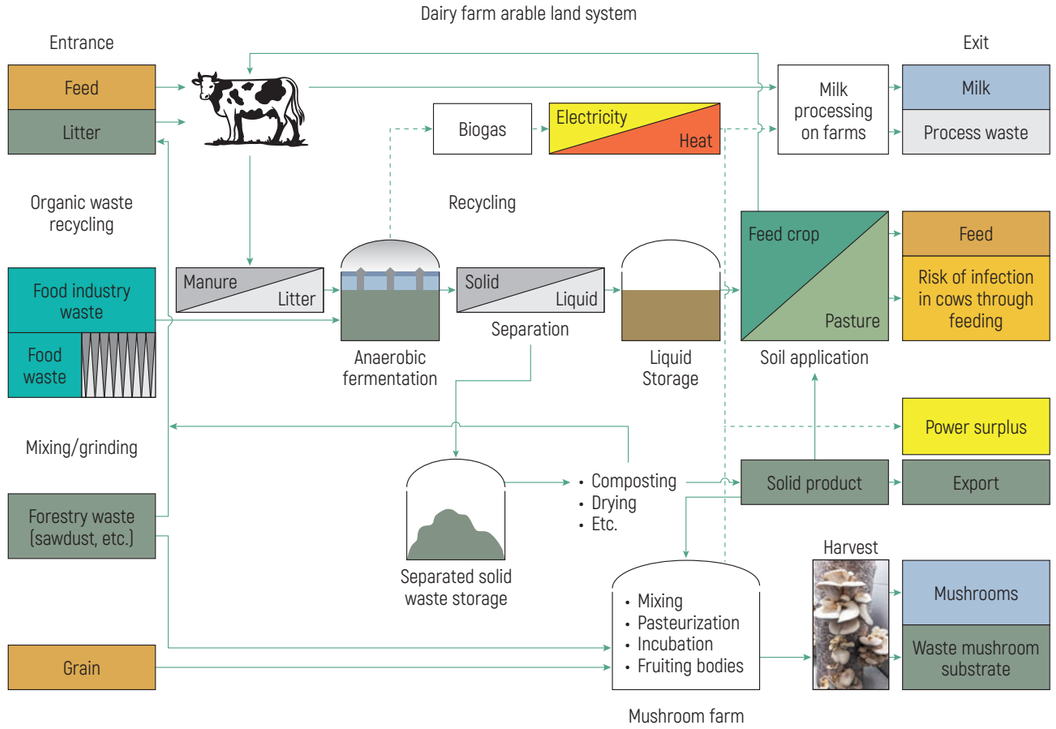

Figure 9 – Zero-waste cycle for agricultural products, including mushrooms [74]

Several media of a certain composition were used to select and optimize mycelium production (Figure 10):

- hardwood sawdust (birch) (94 %) + sugar (0.5 %) + + gypsum (0.5 %) + soft wheat grain (5 %);
- birch sawdust (50 %) + soft wheat straw (50 %);
- birch sawdust (45 %) + soft wheat straw (45 %) + 3BPKO brown coal (10 %);
- soft wheat grain steamed (100 %).

Figure 10 – General view of nutrient media for seed multiplication

The next stage of mushroom cultivation is inoculation with the resulting mycelium of wood or large-sized bags containing a nutrient medium for growing mycothallus of mushrooms (Figure 11).

Figure 11 – Mycothallus of common oyster mushroom grown by the authors

The following compositions have been selected as nutrient media for the production of mushrooms:

- soft wheat straw (100 %) (Figure 12a);
- soft wheat straw (90 %) + 3BPKO brown coal (10 %) (Figure 12b);
- soft wheat straw (98 %) + micro- and macronutrients (2 %) (Figure 12c);
- soft wheat grain steamed (100 %).

a) b) c)

Figure 12 – Mycelium overgrowth of common oyster mushroom in industrial environments with different compositions:
a – soft wheat straw (100 %);
b – soft wheat straw (90 %) + 3BPKO brown coal (10 %);
c – soft wheat straw (98 %) + micro- and macronutrients (2 %)

The choice of media is based on a literature review and economic considerations, i.e., the nutrient composition should be as simple and inexpensive as possible. In addition, the spent substrate blocks are proposed to be used in the future as an animal feed additive, as well as for soil bioremediation.

In order to work out the conditions of extensive cultivation of medicinal mushrooms, a site in a birch grove of the Unitsky's Farm Enterprise (Maryina Gorka, Republic of Belarus) was laid out; logs of various wood species are exposed on it. Based on scientific and practical sources, the authors proposed the following methods of extensive cultivation of mushrooms on wooden stakes:

- modified disc – the log is mounted with the disc downwards instead of upwards;
- double disc – the disc is cut both at the top and at the bottom of the log;
- modified soil – a crosscut is made at the bottom of the upright log to increase the contact surface with the mycelium.

All the wooden stakes are staggered in a common trench. The bottom of the trench is covered with a layer of wood chips (20 cm), which encourage the growth of single mycelium between the logs infested with mycelium of the same species of mushroom.

The yield of seed mycelium and fruit bodies is expected to be determined by weight method, after which a conclusion on the most optimal medium for cultivation will be made.

Conclusions and Future Work

This article examines the beneficial properties of medicinal and edible mushrooms such as reishi (*Ganoderma lucidum*), shiitake (*Lentinus edodes*), oyster mushroom (*Pleurotus ostreatus*), and lion's mane (*Hericium erinaceus*) and studies their effects on the human body. Extensive and intensive cultivation technologies for these mushrooms have been characterized; the possibility of enriching them with elements necessary for human health has been substantiated; the feasibility of using various wastes as nutrient components for mushroom production has been established.

Experiments were carried out on the cultivation of seeds of selected mushrooms (on a particular substrate). Experiments on the selection of media for the cultivation of mushrooms on an industrial scale, as well as for the optimization of cultivation conditions, were carried out.

Further on, the authors plan to carry out research, the results of which will show whether it is possible to obtain a sufficient amount of mushrooms using waste under limited ECH conditions.

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UDC 633.8

Medicinal Plants for EcoCosmoHouse: Selection, Growing Conditions, Scope of Application

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Medicinal plants have been selected for growing in EcoCosmoHouse (ECH) with a description of specific areas of their application as sources of biologically active substances. Methods of obtaining medicinal products from herbs have been considered, methods of organic plant residues utilization have been analyzed. Recipes of combined plant extracts for prevention and treatment of a number of diseases have been proposed.

Keywords:
medicinal plants, extraction, tincture, enclosed biosphere.

Introduction

It is believed that nature can provide everything you need to stay healthy. More and more people are becoming adherents of natural treatment with herbal preparations. This is largely due to the fact that the massive and uncontrolled intake of medication products led to an appearance of a significant number of side effects, a formation of resistance in bacteria, and an emergence of various allergic reactions [1, 2]. Since ancient times, plants have been sources of medicinal raw materials [3].

In EcoCosmoHouse (ECH) [4], i.e., in an enclosed biosphere where no external substances are supposed to be supplied, the process of production of synthetic medication products will be quite laborious, and in some cases unfeasible. For instance, to produce aspirin (acetylsalicylic acid), salicylic and acetic acids are used [5], an esterification reaction is carried out. However, it is obvious that it is impossible to arrange a complete production process to manufacture each drug.

With the above considerations in mind, the purpose of this work is to consider the use of some combinations of plant raw materials under the ECH conditions as an alternative/addition to conventional medicinal products. In addition, an assessment was made of a possibility of growing herbs, and a disposal of organic residues in an enclosed biosphere for subsequent inclusion in the biological cycle.

Compositions and Production Methods of Liquid Medicinal Products

According to the World Health Organization [6], a dysfunction of the cardiovascular system is one of the main causes of death. Further in such a "rating" are infections of the lower respiratory tract, intestinal infections, etc.

It is suggested for the ECH residents to consider prophylactic cardiac, pulmonary, gastrointestinal, external and internal anesthetic compositions produced from medicinal plants. It is important to note that the use of herbal preparations is contraindicated in the presence of individual intolerance to specific components. All recipes presented are developed based on scientific data on the plant effectiveness; the indicated ratios are selected empirically. The optimal duration of the use for tinctures is up to two weeks. In ECH, it is preferable to use alcohol produced from sugar beets or potatoes, for extraction of medicinal plant materials.

Prevention of Cardiovascular Diseases

For a complex therapy of functional disorders of cardiovascular activity, it is suggested to use extracts of hawthorn, mint, motherwort, valerian. Here are the most promising compositions.

• Liquid extract from leaves, berries, and flowers of hawthorn [7] is one of the recognized medicinal products (Figure 1). Due to its rich content of flavonoids, hawthorn possesses a cardiotonic effect. Under the ECH conditions, the hawthorn extract can be obtained by maceration [8]

Figure 1 – Hawthorn, berries

Figure 2 – Mint, generic raw material

in an aqueous medium at a temperature of 37 °C for two hours. An alternative is an alcohol tincture that is prepared in a ratio of 1 : 10 from bush berries and 70 % ethyl alcohol (macerated for a day). A single dose of the drug is 20 drops for adults (0.5 ml).

• A combination of mint, hawthorn, motherwort, and valerian – 1 ml of this solution contains 0.05 ml of mint tincture; 0.15 ml of hawthorn extraction; 0.4 ml of motherwort extraction; 0.4 ml of valerian tincture. The tincture/extraction preparation methods are summarized in Table 1.

Mint (Figure 2) is the most common ingredient in herbal formulations [9]. It contains biologically active components, such as: rosmarinic acid, flavonoids (eriocitrin, luteolin, and hesperidin). Motherwort (Figure 3) possesses a cardiotonic effect [10] and valerian possesses a sedative one [11].

Table 1 – Methods of obtaining tincture/extract used in cardiovascular diseases

Type of tincture/extract	Preparation method
Mint tincture	Extraction with 70 % ethyl alcohol at 1 : 10 during 24 hours
Hawthorn extraction	Water extraction at a temperature of 37 °C during two hours
Motherwort extraction	Extraction with 70 % ethyl alcohol at 1 : 5 during 24 hours
Valerian tincture	Extraction with 65 % ethyl alcohol at 1 : 5 during 24 hours

Figure 3 – Motherwort, generic raw material

Prevention of Pulmonary Diseases

• Buckthorn plantain (Figure 4) is known for its expectorant properties; it relieves dry cough and promotes sputum discharge [12]. Buckthorn plantain juice is prepared from freshly harvested raw materials. The optimal dose is three tablespoons a day.

Figure 4 – Buckthorn plantain, generic raw material

• The composition of herbal medicinal tea is presented in Table 2. The method of preparation: pour 0.5 l of hot water over the herbal repertory and leave for two hours. Take 1/2 cup three times a day.

Table 2 – Components for preparation of herbal tea used at pulmonary diseases (calculation per 0.5 l of water)

Type of raw material	Weight, g
Althea, root (Figure 5a)	8
Wild chamomile, flowers (Figure 5b)	8
Foalfoot, generic raw material (Figure 5c)	8

a)

b)

c)

Figure 5 – Herbal tea components: a – althea, root; b – chamomile, flowers; c – foalfoot, generic raw material

Althea officinalis is a traditional herbal component of medicinal products that are used for upper respiratory tract diseases accompanied by dry cough [13]. Althea officinalis in combination with other plant raw materials enhances the beneficial effect of herbal tea. The composition of chamomile flowers includes flavonoids, quercetin, apigenin, patuletin, luteolin, and terpenoids [14]. Flowers of foalfoot possess anti-inflammatory and antioxidant activity because they contain sesquiterpenes, phenols, flavonoids, and alkaloids [15].

Prevention of Gastrointestinal Diseases

For this purpose, two types of herbal medicines are suggested for use, the main components whereof have proven efficacy in treatment of gastrointestinal diseases.

• Pour the herbal mixture (the composition is presented in Table 3) with boiling water, leave to stay for 12 hours. Take one teaspoonful four times a day 30 min before meals.

Table 3 – Components to prepare a tincture used at gastrointestinal disturbances (calculation per 1 l of water)

Type of raw material	Weight, g
Buckthorn plantain, leaves	40
St. John's wort, generic raw material [16]	40
Centaury, generic raw material [17]	20
Waterwort, generic raw material [18]	40
Sweet flag, root [19]	10
Peppermint, generic raw material	10
Knotweed, generic raw material [20]	20
Yarrow, flowers [21]	15
Caraway, seeds [22]	6

St. John's wort (Figure 6a) contains many useful substances that ensure its healing properties: myrcene, cineole, vegetable alkaloids, saponins, ascorbic acid, and group B vitamins. Centaury (Figure 6b) contains alkaloids, bitter glycosides, flavonoids, triterpenoids, phytosterols, and essential oils. Medicinal components of the waterwort (Figure 6c) are flavonoids, chlorogenic and caffeic acids, vitamin C, thiamine, tannins, alkaloids, and essential oils. Sweet flag root (Figure 6d) contain bitter glycosides, ascorbic acid, tannins, borneol, and eugenol. Knotweed (Figure 6e) is a source of flavonoids, vitamins C and K, coumarins, tannins. Yarrow flowers (Figure 6f) are distinguished by a large amount of vitamin K, methyl betaine, essential oils, sesquiterpene lactones, cineoles, borneols, and camphor. Caraway seeds (Figure 6g) – a storehouse of fatty acids, essential oils, vitamin B, and minerals.

a)

b)

c)

d)

e)

f)

g)

Figure 6 – Raw materials: a – St. John's wort, generic raw material; b – centaury, generic raw material; c – waterwort, generic raw material; d – sweet flag, root; e – knotweed, generic raw material; f – yarrow, flowers; g – caraway, seeds

• Silverweed cinquefoil leaves (Figure 7) [23] contain vitamin C, tannins, flavonoids, and essential oils. Liquid dosage forms of this plant are characterized by a hemostatic, astringent, antispasmodic effect. A tincture preparation method: pour 20 g of raw material with 1 l of boiling water. The administration dosage is one glass thrice a day.

Figure 7 – Silverweed cinquefoil, generic raw material

External Anaesthetic Preparations

• Juniper berries (Figure 8) are distinctive with their rich composition of essential oils, vitamins, microelements, monoterpenes; they possess antiseptic and antibacterial properties. A tincture preparation method: pour 10 juniper berries with 70 % ethyl alcohol (1 l), leave to stay for 24 hours [24].

Figure 8 – Juniper, berries

• Peppermint can act as a medicinal raw material for preparing an astringent that relieves skin inflammation. A tincture preparation method: pour 50 g of peppermint with 70 % ethyl alcohol (1 l), leave to stay for two days.

Internal Anaesthetic Preparations

• Common St. John's wort (Figure 6a) contains naphthodianthrone, xanthones, flavonoids, phloroglucinols [25]; it is used for treatment of gastrointestinal diseases and metabolic disorders, as well as for manufacture of over-the-counter herbal antidepressants. An extract preparation method: infuse 10 g of dried and cropped plant in 1.5 glass of boiling water. Take 1/3 cup orally once a day.

• Sagebrush (Figure 9) is known for its high concentration of essential oils (thujone, thujol, fellandren), as well as tannins, absinthin, and flavonoids; it is considered as an excellent appetite stimulant. An extract preparation method: pour 2 g of chopped herbs with 0.5 l of boiling water [26].

Figure 9 – Sagebrush, generic raw material

Experimental Samples

For every suggested composition, it is planned to make prototypes from raw materials, and then obtain liquid drugs by extraction. During the writing of this article, the experimental material is being tested (taste properties, quality indicators are evaluated); then, if required, they will be finalized (Figures 10, 11).

Figure 10 – Samples of studied combined compositions

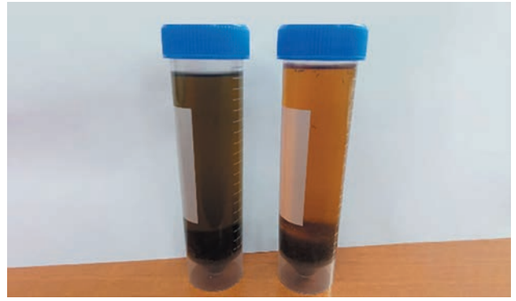

Figure 11 – Extractions: left – alcoholic; right – aqueous

Area and Environmental Requirements for Growing Plants in ECH

Table 4 presents the size of areas required for growing plants that will be used as raw materials in preparation of the above liquid medicines. The calculation took into account the reference yield for each plant [27]. Additionally, the following important fact was taken into account: harvesting occurs once a year (with a subsequent drying of the herbal material). It is difficult to predict exact annual needs for these medicines, as they may be required in different quantities during a year, dependent on the incidence of human diseases. Consequently, it is advisable to have a stock of harvested and dried herbs/fruits in ECH for a quick response to the occurrence of various diseases. It should be also taken into account that the shelf life is no more than seven days (at a temperature of 0–4 °C) for aqueous tinctures and up to three months for alcoholic tinctures.

Table 4 – Size of areas intended for growing medicinal plants (calculation per 100 persons)

Kind of plant	Description	Area, m^{2*}
Hawthorn	Deciduous multistemmed tree	110
Mint	Perennial herbaceous plant	10
Motherwort	Perennial plant, bush	20
Valerian	Perennial herbaceous plant	10
Buckthorn plantain	Perennial herbaceous plant	5
Althea	Perennial herbaceous plant	10
Chamomile	Yearling herbaceous plant	8
Foalfoot	Perennial herbaceous plant	5
Centaury	Perennial herbaceous plant	5
Cudweed	Yearling herbaceous plant	5
Sweet flag	Perennial herbaceous plant	10
Knotweed	Yearling herbaceous plant	5
Yarrow	Perennial herbaceous plant	10
Caraway	Yearling herbaceous plant	10
Juniper	Perennial conifer	12
St. John's wort	Perennial herbaceous plant	30
Sagebrush	Perennial herbaceous plant	10

* The area is stated in regards to one tier planting.

The total area required for cultivation of medicinal plants per 100 persons is 275 m^2. However, with multi-tiered planting and an appropriate space optimization, the same plants can be grown in ECH on an area of 100 m^2 or less.

The tier height built into the project that is also dependent on the type of plants, is sufficient to allow collection of medicinal plant products both manually and with the use

of automated systems. A general requirement for the tier height is as follows: the distance from the upper part of the plants to the light source shall be at least 15–20 cm.

Considering beneficial properties of medicinal herbs, we believe it justified to allocate a natural area of 100 m^2 to cultivate them in ECH (1 m^2 per every resident). The optimum conditions for the growth of the selected plants in an enclosed system are as follows: a temperature of 21–25 °C, humidity 55–60 %, high quality local illumination with an intensity of 100,000 lx [28].

Disposal of Organic Residues of Medicinal Plants

The main method for disposal of organic residues of medicinal herbs (leaves, roots (dry, rotten), branches) is their destruction by micro- and macroorganisms, followed by a transfer of all nutrients into humus (the basis of soil fertility) and their subsequent return into the cycle. In this way, plant waste will be converted into insoluble salts of humic acids (humus), and then, through anaerobic microorganisms, into a soluble form that can be directed to plants as nutrients [28]. Some organic residues can be used for cultivation of cellulose-degrading fungi.

Conclusions and Future Work

The authors have proposed a number of herbs useful for humans for the purpose of cultivation in ECH and have calculated the area under crops. In addition, formulations of liquid dosage forms are presented (cardiac, pulmonary, gastrointestinal, external and internal analgesics).

As at the time of compiling this paper, experiments are underway aimed at improving the content of these medicinal preparations (adding new components or excluding those that do not carry any functional payload). It is in our plans to expand the list of alcohol- and water-based medicinal products, taking into account the above list of medicinal herbs: five new formulations are planned to development. During the research, the mutual influence of ingredients will be mandatorily considered, including their proportions and flavor properties.

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UDC 574.4

Adaptation Processes Within the Enclosed Ecosystem Model

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The following article continues the research carried out by the authors in 2020 regarding the creation of an enclosed ecosystem model. This work describes the processes of enclosed ecosystem self-regulation and traces the changes within the populations of aquatic and terrestrial animals and plants. The article analyzes the adaptive functions within and between all biological components: studies the circulation of species, extinction, and the dynamics of their adaptation. The peculiarity of the research lies in the study of the established ecosystem model consisting of a certain set of organisms, as well as in the determination of the current interactions between them.

Keywords:
enclosed ecosystem, populations, species interaction, enclosed environment.

Introduction

There is a widespread belief that nature is always in a state of equilibrium. According to this point of view, the number of species fluctuates until it reaches a stationary definite value resulting from the energy constraints of their habitat. It's true that climatic changes and other factors can delay population coming to a sustainable state, however, the optimal balance will be eventually reached at each site [1, 2]. It has been proved with reason that biodiversity increases the stability of processes in the transforming surrounding world [3]. There are three main mechanisms of how the biodiversity affects the ecosystem properties:

1) internal reactions to environmental fluctuations;

2) differences in the speed with which species respond to disturbances;

3) decrease in the competition strength.

The first two aspects involve temporal complementarity between species; the third is the result of functional complementarity, where competition between species is reduced for the sake of overall survival. Additional mechanisms for establishing stability include selection effects, changes in behavior (due to the interaction of species), and cooperation (as a result of trophic or non-trophic relationships and spatial heterogeneity) [4, 5].

In 2020, the authors created the enclosed ecosystem model installation [6]. During the seven months of isolation, the organisms have adapted and began to build new relationships. All individuals occupied their ecological niches. A stable and productive state of the population directly depends on the biotic circulation in the organized landscapes of the isolated space model. Planned geolandscapes and hydrospheres contain a certain set of chemical elements, as well as the concentration of bioorganic matter [7].

All elements circulate in the ecosystem between geo- and hydrosphere. Such a movement ensures an equal distribution of compounds in the model, which leads to a state of equilibrium and, as a result, to the preservation of the population numbers. In October 2020, sealing and isolation of the ecosystem prototype was carried out.

The main goal of this article is to analyze the dynamics of growth and development of all living organisms inhabiting the enclosed ecosystem model and to study their influence on each other. In addition, the authors considered important to investigate the relationships that have developed between species in the aquatic and terrestrial environment, as well as to establish which species have occupied a dominant position, and which are on the verge of extinction. The authors suggest that this work will lead to a conclusion about the possibility of reaching the condition in which the ecosystem can function indefinitely.

The obtained results are planned to be used in the design of the EcoCosmoHouse on Planet Earth (ECH-Earth) facility, in which the adaptation of biological components will take place for a long period of time, allowing to solve various problems and answer new emerging questions. One of the options for adapting to the conditions of the surrounding world can be mini-ecosystems created on Earth, for example, in capsules of the General Planetary Vehicle (GPV) [8].

The section "Dynamics and Natural Selection of Plants in the Enclosed Ecosystem Prototype" describes the state of growth and development of plants in isolation. The next section presents the animals introduced into the ecosystem and shows how they managed to come to a stable state of sealing. The final part demonstrates the results of ecosystem observations and describes further directions of the research.

Dynamics and Natural Selection of Plants in the Enclosed Ecosystem Prototype

The functioning of an enclosed ecosystem depends on many factors, including conditions of the aquatic and terrestrial environment, as well as the composition and number of living beings inhabiting it [9, 10].

Air humidity began to change during the growth and development of plants in the terrestrial part of the ecosystem prototype. In October 2020 (at closing), the humidity fluctuated between 70–85 % (often a similar range of fluctuations was associated with external temperature indicators).

As soon as the plants entered the stage of sustainable growth, the humidity settled at 80 % and became constant. The transpiration of air and water from the plant stomata allows keeping this indicator stable. Excess moisture is not formed due to the complete openness of the water surface [11, 12].

The temperature in an enclosed environment depends on the readings of the thermometer outside the glass, as well as on the result of the activity of microorganisms living in soil and water [13]. For example, when the photosynthetic device is operating, the leaf surface gets heated, and its cooling is performed due to the evaporation of water, thereby increasing the temperature in the enclosed ecosystem prototype.

A struggle for existence arose between all plants of the isolated space. Each of the organisms entered into competition for resources not only with other species representatives but also within their own species. A similar nature of the relationship was noted due to more accelerated development of some (more adapted) individuals and the oppression of others.

The following plants were introduced into an enclosed environment: higher angiosperms, such as sparrowgrass (*Asparagus officinalis* L.), Caucasian feather grass (*Stipa caucasica* Schmalh.), gray fescue (*Festuca glauca* Lam.), festulolium (*Festuca* × *Lolium*), chick-pea (*Cicer arietinum* L.), green pea (*Pisum sativum* L.), purple alfalfa (*Medicago sativa* L.); sporophytes, such as hair-cap moss (*Polytrichum commune* Hedw.), fern adiantum (*Adiantum capillus-veneris* L.).

The moss populations most likely adapted to the changed conditions, as the new green shoots were noted. Higher angiosperms also quickly adapted to the outside world, however, unlike mosses and ferns, they began to form reproductive organs (flowers) and bear fruit successfully.

As is known, after ripening the plant seeds get into moist soil where they germinate; and this is how their constant population is maintained. Limitations in the land space of the enclosed environment prototype lead to the struggle for resources (mineral nutrition, water, sun rays, etc.) between plants [14]. During this process, the most beneficial are the species that are capable of vegetative reproduction and the formation of a large number of shoots with additional roots.

Another factor of stabilization in an isolated area is the presence of pathogenic microbiota. When the enclosed ecosystem was launched, a mold of the genus *Fusarium* was introduced. This phytopathogenic organism helps to get rid of weak plants, and also destroys their fallen leaves.

Most of the terrestrial species were eliminated from the populations, and in some cases, they completely died. So, due to high humidity and lack of resistance to the fusarium pathogen, the adiantum fern (*Adiantum capillus-veneris* L.) died, thereby transferring nutrients to the soil for further circulation of substances.

Caucasian feather grass (*Stipa caucasica* Schmalh.), on the contrary, acquired resistance to the pathogen, as a result of which the active development of the plant was observed (Figure 1).

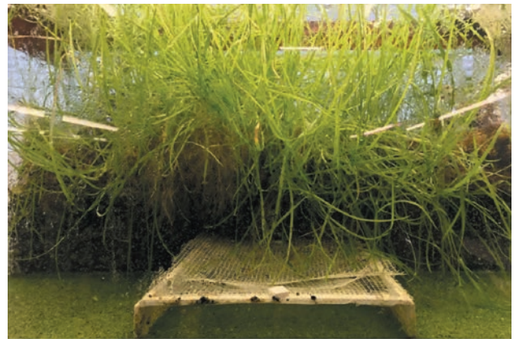

Figure 1 – Sprawling Caucasian feather grass (*Stipa caucasica* Schmalh.)

Stipa caucasica Schmalh. is able to form additional roots at the nodes on the shoots, mastering new feeding areas. In the place of root formation, a vegetative bud is also formed. They all give rise; thus, the Caucasian feather grass colonizes large parts of the land. The dynamics of this organism development is shown in Figure 2.

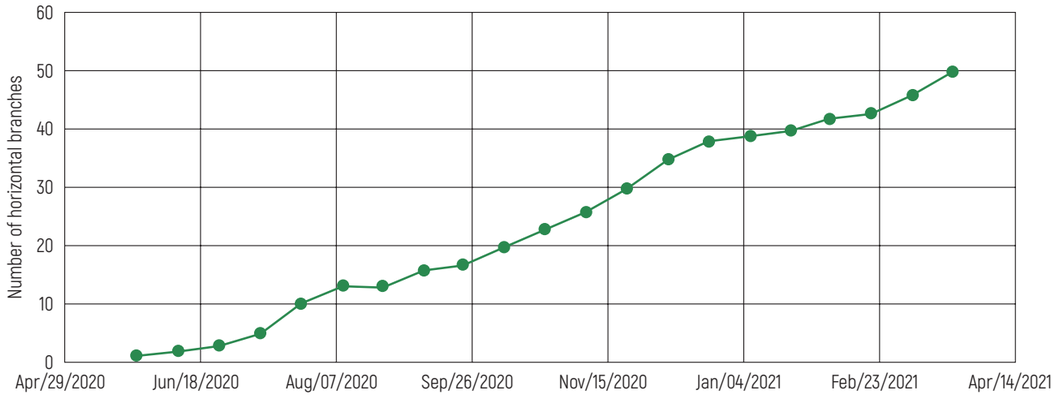

Figure 2 – Dynamics of development of *Stipa caucasica* Schmalh.

An even transportation of nutrients from the root system, as well as products of photosynthesis from leaves, is carried out due to the developed xylem and phloem. The active course of the photosynthesis process is demonstrated by the abundant green mass of the plant.

The green pea (*Pisum sativum* L.) also shows an increase in biomass and signs of stable adaptation. Figure 3 shows the flowering stage on January 5, 2021.

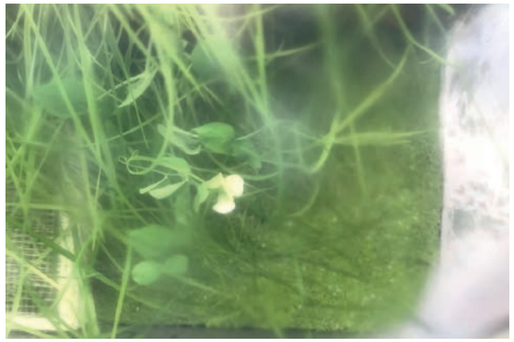

Figure 3 – Flowering stage of the green pea (*Pisum sativum* L.) in an enclosed ecosystem model

It is worth noting the rather rapid adaptation of aquatic plant cultures, however, the imbalance of macro- and microelements led to a massive pestilence of aquatic inhabitants and plants. Stringy moss (*Leptodictyum riparium*) and umbrella hairgrass (*Eleocharis vivipara*) showed active growth in the first month, but on March 22, 2021 they were at the stage of oppression. Flame Moss (*Taxiphyllum sp.*) has taken a dominant position in the aquatic ecosystem among green spaces. Slow development was shown by lomariopsis (*Lomariopsis lineata*), hemianthus Cuba (*Hemianthus callitrichoides*), pogostemon helferi (*Pogostemon helferi*), anubias afzelii (*Anubias afzelii*), while no complete suppression was observed.

In addition, one of the important elements of stability is the balance of oxygen and carbon dioxide in the water. For seven months, with a periodicity of two weeks, there was a cyclical growth of algae, and then a decrease in their number in the water. Such fluctuations are associated with the accumulation of carbon dioxide during respiration of aquatic organisms; as a result, the algae began active photosynthesis, due to which its biomass increased.

Immediately after the ecosystem formation, the external conditions of the surrounding space affected the animals and plants in an enclosed structure. This fact was manifested in a sharp decrease in their number (for example, shrimp) and even in the disappearance of species (like drying of the adiantum fern). Later, living biological components acquired resistance to the factors of the local habitat and gradually began to influence it. This feature is primarily associated with plant transpiration. Thus, the development of plant cultures of the enclosed system prototype on land led to various changes in the concentration of moisture in the air, as well as to the accumulation of oxygen in the described isolated system.

Soil microorganisms and molds ate weak developing plants, mainly perennial grasses.

Features of the Animals' Development Dynamics

The 2020 study made it possible to obtain primary data on the development of animals [6]. The study as well continued after the constructed installation was closed.

The list of animals originally included in the ecosystem is as follows: black ant (*Lasius niger*), woodlouse (*Platyarthrus hoffmannseggii*), aphid (*Aphidoidea spp.*), orb snail (*Planorbis sp.*), assassin snail (*Anentome helena*), shrimp (*Neocaridina*).

Figure 4 shows a black ant. When creating an enclosed environment model, two *Lasius niger* queens were inhabited. Weekly observations confirmed the presence of about 10 individuals of working insects, which characterizes the stable development of the population and the creation of a colony of ants with one queen.

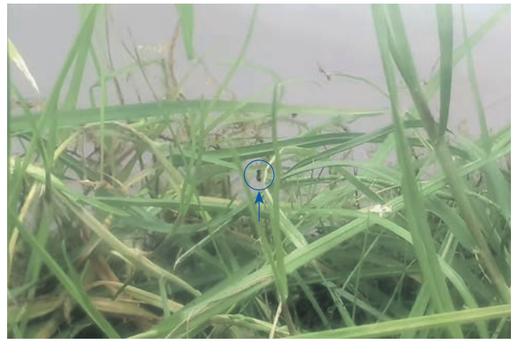

Figure 4 – Black ant (*Lasius niger*) in an enclosed ecosystem model

The number of aphids (*Aphidoidea spp.*) has decreased from 30 to five organisms, which may be due to insufficient nutritional base and excess moisture. However, this decline did not affect the overall stability. Ants have found new sources of food.

It is noteworthy that in the ecosystem, in addition to the introduced animals, there were accidentally found other ones that could've possibly got there together with the soil. In Figure 5, the arrow indicates woodlouse (*Platyarthrus hoffmannseggii*); a feature of its life is feeding on ant droppings or mold. Often this type of crustacean is found near the nests of the black ant (*Lasius niger*), which were settled in an isolated space. Thus, the conditions formed in the ecosystem turned out to be suitable for the growth and favorable existence of *Platyarthrus hoffmannseggii*.

Figure 5 – Woodlouse (*Platyarthrus hoffmannseggii*) in an enclosed ecosystem model

All animals, such as shrimp, orb snails, cyclops, and assassin snails, underwent active development in the aquatic environment. Figure 6 shows the abundance of orb snails (*Planorbis sp.*).

Figure 6 – Orb snails (*Planorbis sp.*) in an enclosed ecosystem model

The number of snails varied during the entire observation period: from 23 to 64 individuals, depending on the conditions of the surrounding space and the availability of food. The graph in Figure 7 reflects the growth dynamics of *Planorbis sp.* from May 26, 2020 to March 26, 2021. The number of coil snails was monitored by three assassin snails (*Anentome helena*) (data as of March 26, 2021).

Another representative of the animal aquatic kingdom is the *Neocaridina* shrimp. At the initial settlement in the ecosystem, their number decreased by 26 % [6].

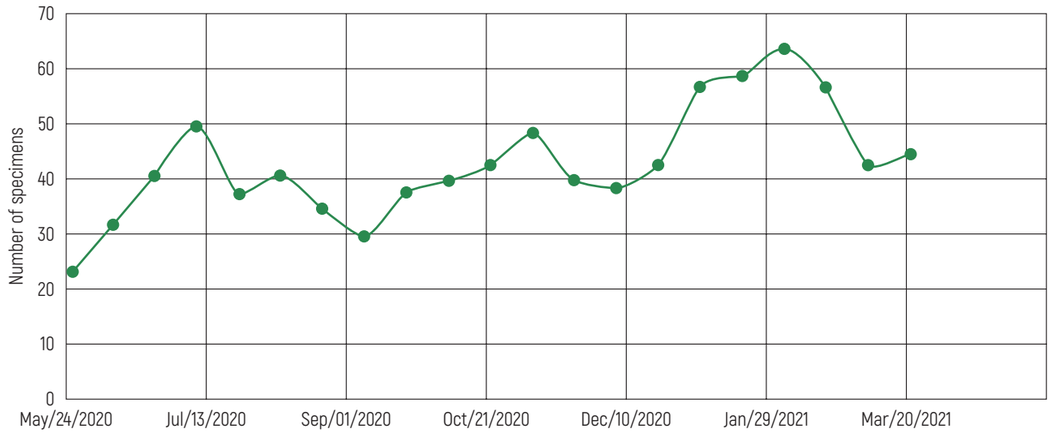

Figure 7 – Dynamics of the number of individuals of orb snails (*Planorbis sp.*)

However, after passing through the adaptation process, some of the shrimp thrived; there were 11 adults as of March 26, 2021 (54.5 % increase since June 10, 2021). Figure 8 shows a shrimp bearing eggs.

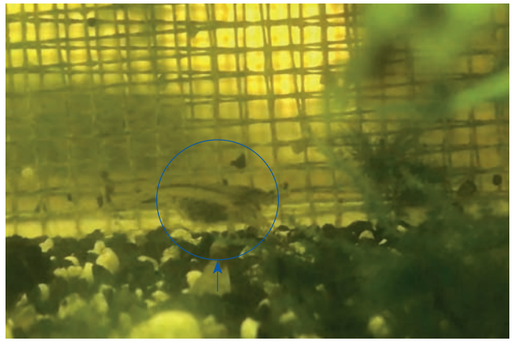

Figure 8 – *Neocaridina* shrimp with eggs

Conclusions and Future Work

Based on the results obtained in the course of the study, it can be established that, after nine months of existence in an enclosed environment, the ecosystem was approaching a state of equilibrium. Some plant species, such as fern (*Adiantum capillus-veneris*), stringy moss (*Leptodictyum riparium*), and umbrella hairgrass (*Eleocharis vivipara*) were eliminated from the population. The other part, including asparagus (*Asparagus officinalis* L.), Caucasian feather grass (*Stipa caucasica* Schmalh.), and green pea (*Pisum sativum* L.), took the dominant position.

The aphids had the most difficult adaptation process; their population has greatly decreased and is probably on the verge of extinction. Possible conclusion is that this selected organism is not quite suitable for the existing ecosystem. Shrimp also showed long-term adaptation, however, they were able to balance their condition; increase in their numbers was noted on March 26, 2021.

During this period, the ants were still in the course of adaptation (their number did not correspond to the expected number of an ant colony of two queens). Obviously, this is due to an insufficient nutritional base. In the future (with the development of vegetation and the corresponding changes in the environment), food will become sufficient, and therefore an increase in the *Lasius niger* number is expected.

It is planned that the monitoring of the created ecosystem model will be conducted for three years. This time interval is due to the following reason: since the rate of change of the components of an isolated space decreases (compared to that which was immediately after the closure), it means that statistically significant differences can be seen at least after three years of the existence of isolation. Accordingly, an analysis of the growth of populations of animals and plants will be carried out, as well as their interaction with the emerging dominance of one species and possible elimination from the population of another will be studied.

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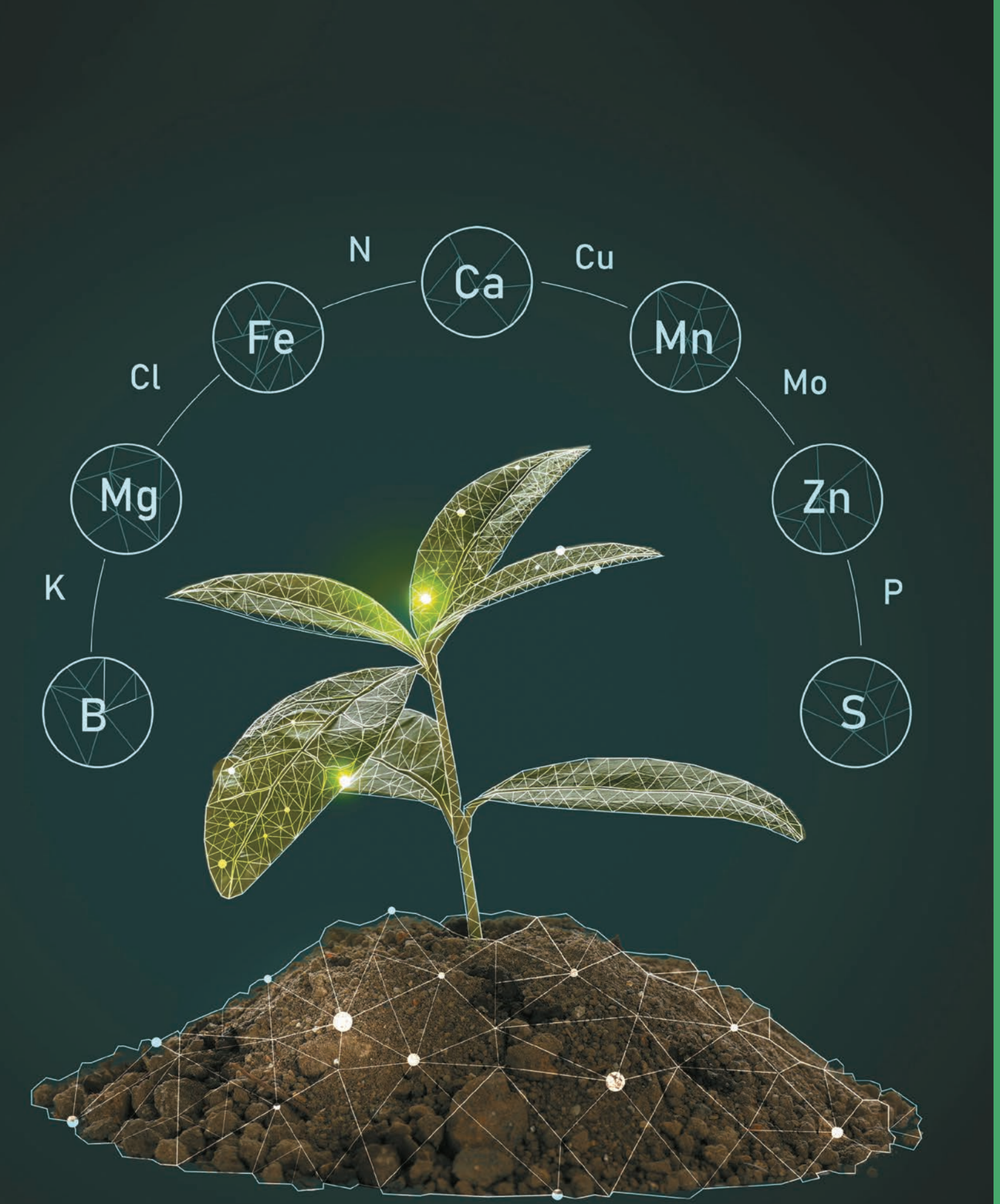

UDC 579.64

Minimal Association of Organisms for Soil Fertility

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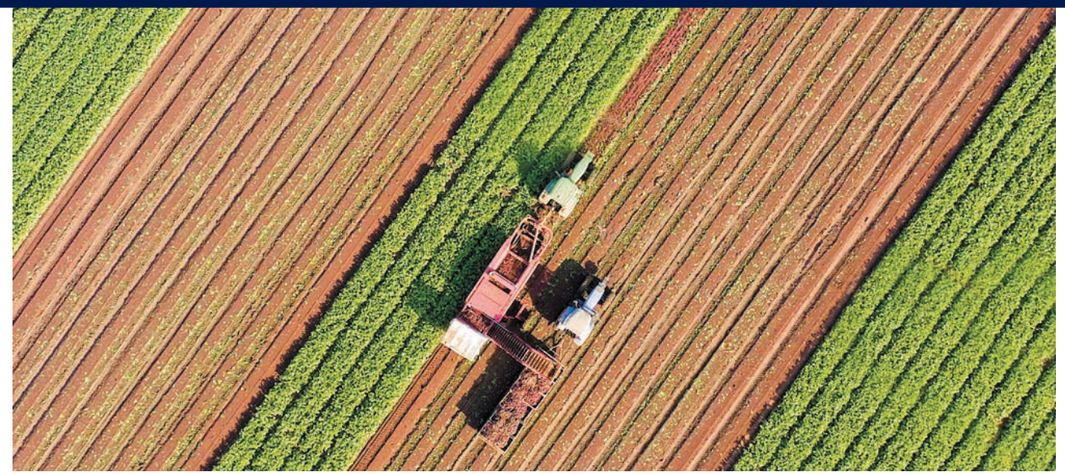
We have considered the relationship between soil microorganisms and plants cultivated on it. The research concerned the types of fungi, bacteria, and algae that improve the growth performance of vegetation.
A minimal association of organisms that increases soil fertility has been selected. We have carried out an analysis of a complex effect the association that consists of worms, microorganisms, and algae produce on accumulation of organic and mineral substances in the soil available for plants and other microorganisms, as well as its impact on the growth and development of watercress (*Lepidium sativum*).
The experiment was carried out on a soil containing a minimal quantity of macro- and microelements.
The study is relevant in the context of working out a possibility of developing new, impoverished lands, and is especially important for creation of enclosed ecosystems (for instance, EcoCosmoHouses on Planet Earth (ECH-Earth)).

Keywords:
soil, association of organisms, bacteria, algae.



Introduction

Agricultural activity is the first anthropogenic impact of man on land resources that first started disruption in the course of natural processes in soil and nature in general. With the development of intensive agriculture that employs actively chemical fertilizers and plant protection products, that negative anthropogenic interference became destructive [1]. There is no other sphere of economic activity as agriculture where natural factors manifest themselves with such force in formation of technological production processes [2–4]. Repeated cultivation of agricultural land worsens its fertility. Different types and forms of mineral fertilizers affect soil properties differently [5, 6]. Fertilizers introduced into the soil enter into complex relationships with it. All sorts of transformations are observed that depend on a number of aspects: properties of fertilizers and land, weather conditions, and agricultural techniques. The way how changes occur in certain types of mineral fertilizers (phosphorus, potash, nitrogen ones, etc.) determines their effect on soil fertility [7, 8]. Their imperfect chemical composition is the primary reason of the negative consequences for the environment caused by non-rational use of fertilizers.

Certainly, minerals introduced into the soil in high concentrations increase the yield. However, they also pollute nature, which means that thereby, they harm the soil ecosystem [3, 9]. Their use leads to intoxication of plants and animals. High doses of nitrogen in the soil also lead to the death of soil microorganisms and animals (roundworms, annelids, arthropods, etc.) [2, 4, 10].

Microorganisms decompose most of the soil organic matter into inorganic minerals that are further absorbed by plant roots as nutrients. This process is referred to as mineralization. Dependent on conditions whereunder such decomposition occurs, a certain part of the organic matter is not mineralized; instead, it is included in a process known as soil humification. Organic polymers are resistant to the action produced by microorganisms and represent humus. Such stability means that humus is integrated into the permanent soil structure, thereby improving it.

Humus is formed from organic and mineral substances. It accumulates gradually discharged mineral elements [9] that are released from its small particles resulting from vital activities of microorganisms, protozoa; large particles of organic matter (granules) are formed by soil animals [2]. Consequently, humus is an integral part of plant nutrition that are, in their turn, the main suppliers of organic matter that enters the soil in the form of organic residues [2, 11].

Most microorganisms are engaged in symbiotic interactions with plants. Such bacteria and microscopic fungi are called rhizosphere microorganisms [6, 12–14]. These associations are capable of fixing nitrogen in the soil, as well as converting other elements into an accessible form: iron (chelated form), potassium (in the form of ions), and phosphorus (phosphates) [6, 13, 15].

A fertile layer formation is a long process that took more than one thousand years. Accordingly, soil degraded due to intensive farming will need a long time to recover in nature. Therefore, while creating enclosed ecosystems, difficulties will arise in formation of a stable association of organisms necessary for an efficient growth and development of plants without using chemical fertilizers and pesticides.

The establishment of a minimum association will further simplify the tasks of developing depleted lands, which will be also applicable in construction of EcoCosmoHouse (ECH) that is an enclosed ecosystem [16, 17].

The purpose of this research is to establish a relationship between organisms introduced into the soil and an improvement in the growth and physiological properties of the watercress (*Lepidium sativum*). When selecting the biological composition of the soil, emphasis was placed on trophic relationships between organisms that belong to a different type and even a different kingdom.

The objectives of the research are to determine, based on the data obtained from scientific sources, a list of organisms contributing to soil improvement; to experimentally evaluate the influence of the association formed on the growth and development of watercress; to compare the cultivation process on sand, sound soil, and soil improved by the association of organisms.

Reference Review of Microorganism Diversity

Types of Microorganisms Found in the Soil

Up to 10 bln bacterial cells inhabit one gram of fertile soil, as well as live in and around the roots of plants (rhizosphere).

As a rule, soil contains organisms that belong to *Proteobacteria*, *Actinobacteria*, and *Firmicutes* types [18, 19]. The main location of bacteria is the root zone. Here, the highest concentration of organic polymers is observed that are formed resulting from vital activities of bacteria or root exudates, as well as the die-away of plant roots and rhizoids, which is the dominant cause of the huge number of bacteria in the rhizosphere.

The rhizosphere includes a lot of various symbiotic relationships. A key irreconcilable interaction in the root zone occurs between rhizobacteria and pathogenic microorganisms. This type of relations is most important primarily for crops grown in agriculture and forestry [20, 21].

Pseudomonas spp. are found capable of eliminating a significant amount of a mold (fungal) association that is pathogenic for plants in the soil. A well-known fact is that *Pseudomonas putida* suppresses the soil fungal pathogen *Verticillium dahliae* [20, 21, 9]. *Burkholderia* and *Pseudomonas*, as well as *Serratia species,* can produce pyrrolnitrin, an antibiotic.

Fungal Destructors in the Rhizosphere

In most cases, bacteria are involved in decomposition of simple soluble substrates, whereas fungi are considered the main destructors of solid, fragile substrates. In addition, fungi that specialize in decomposition of the most common polymeric substances (cellulose, hemicellulose, lignin) produce extracellular enzymes. Monomers and oligomers (such as sugars and disaccharides) released by extracellular hydrolytic enzymes are substrates that these fungi use to absorb.

Algae and Cyanobacteria in Soil

Filamentous cyanobacteria are key organisms involved in the biological formation of soil crust in all biomes of the world. Filamentous green algae can play a particularly important role in temperate, arctic, and high-mountain regions, as well as in certain arid savannah ecosystems [9, 22, 23].

The world of soil-inhabiting cyanobacteria and eukaryotic algae is diverse; however, only some of them are actually responsible for a formation of the fertile layer. The most important cyanobacteria are *Microcoleus*, *Nostoc*, *Scytonema*, and *Stigonema* [22, 23].

Minimum Soil Microbiome to Improve and Restore Its Fertility

Taking into account scientific data and practical application of soil microorganisms in organic agriculture, we have selected the most appropriate soil associations to solve a set of issues on improvement of soil fertility through vital activities of microorganisms [24, 25]. The optimal association has been composed based on the minimum necessary tasks that must be performed by soil organisms for a stable growth and development of plants [26]: nitrogen, phosphorus, and potassium conversion into an accessible form; organic matter production; maintenance of the required granulometric composition of the soil [27, 28].

To increase productivity, the topsoil should be enriched with organic matter, in particular, through cultivation

and artificial introduction of organic matter. Soil algae added result in their accumulation of organic matter and phytohormones while consuming carbonic acid gas and water, as well as creation of a nutrient base for other beneficial organisms [29].

Organic substances that saturate soil (sugars, fats, proteins, etc.) primarily feed microscopic fungi and bacteria that further convert, in the process of their vital activity, organic compounds from one form to another, more accessible to the next association [30]. An example is nitrogen fixation. This element is accumulated in the soil in two main ways: during a decomposition of proteins; nitrogen fixation from air and its further nitrification. Moreover, nitrogen is a component that can be washed out of the soil with melt and rainwater [31]. In addition, nitrifying bacteria convert ammonium from nitrogen fixators into nitrite that can be converted by nitrate bacteria into nitrate and supplied to plants in even doses [32, 33].

The soil contains a large amount of phosphorus and potassium in a state bound to the mineral part of the soil. To release these elements and convert them into a form accessible to plants, it is necessary to add phosphate and potassium-mobilizing bacterial species – *Bacillus subtilis*, *Bacillus megaterium var. phosphaticum*, *Azotobacter chroococcum*, *Enterobacter*, *Paenibacillus polymyxa* [34, 35].

The growth of microorganisms increases the volume of the organic substance nutrient base for other microorganisms included. Pathogenic microorganisms also enter the soil with plant residues. To eliminate such a load, the soil association includes microorganisms that emit natural antibiotics, which allows controlling the number of pathogenic bacteria [36, 37].

Materials and Research Techniques

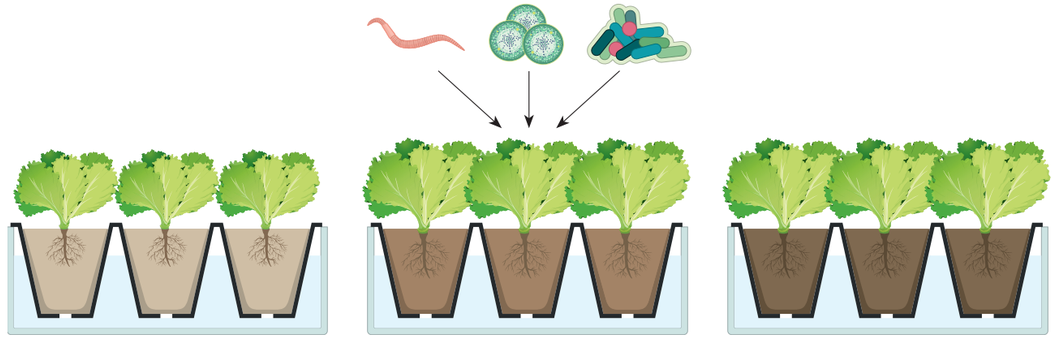
Watercress was chosen as one of the universal model organisms that is optimal for testing the influence of a growing substrate composition.

Three substrates were used to cultivate *Lepidium sativum*:

- quartz sand (SiO_2) with no organics and mineral salts added (negative control) (Figure 1, Sample No. 1);
- common soil with an addition of a complex of selected organisms (sterilized soil from the Unitsky's Farm Enterprise is used as a soil) and a humus content of about 2 %, $N_{40}P_{140}K_{380}$ (nitrogen – 40 mg/l, phosphorus – 140 mg/l, potassium – 380 mg/l) (Figure 1, Sample No. 2);
- efficient universal soil for plants (commercially available) containing $N_{150}P_{200}K_{450}$ (nitrogen – 150 mg/l, phosphorus – 200 mg/l, potassium – 450 mg/l). It mostly consists of peat with sand added (Figure 1, Sample No. 3).

At the end of the growing season (25–30 days), the following indicators are assessed:

- number of microorganisms before and after cultivation on a solid nutrient medium using the QMAFAnM (Quantity of Mesophilic Aerobic and Facultative Anaerobic Microorganisms);
- specific features of plant vegetative growth at each development stage (sowing, shoots, cotyledon ejection, phase of three true leaves, lateral development): leaf area, average crop growth, number of laminas;
- total plant biomass (at natural humidity);
- dry plant biomass;
- photosynthesis intensity.



No. 1 No. 2 No. 3

Figure 1 – Experimental setup scheme

Photosynthesis Intensity Measurement Technique

Leaves of experimental plants, previously cut across the nervures, are completely submersed into distilled water (its temperature should be at least 20 °C). Then the container with the leaves is placed under an intense light source, and the frequency of gas bubble (O_2) occurrence is recorded per one minute. The light source is moved to varied distances, and gas emission is measured. Gas release on the surface of the laminas indicates the progress of a photosynthesis process in the leaves, while the gas amount indicates the photosynthesis intensity [38]. All samples were tested under identical conditions, including the same parameters of the water temperature and light intensity.

Net Productivity Measurement Method for Plant Photosynthesis

Plant samples were taken with intervals of 10 days in the amount of 10 pieces. First, the raw plants were weighed, then leaves were separated, and their area was determined. Then all parts were dried to the air-dried mass and weighed again.

The calculation was made by the formula:

$$NPP = \frac{V_2 - V_1}{0.5(L_1 + L_2)n},$$

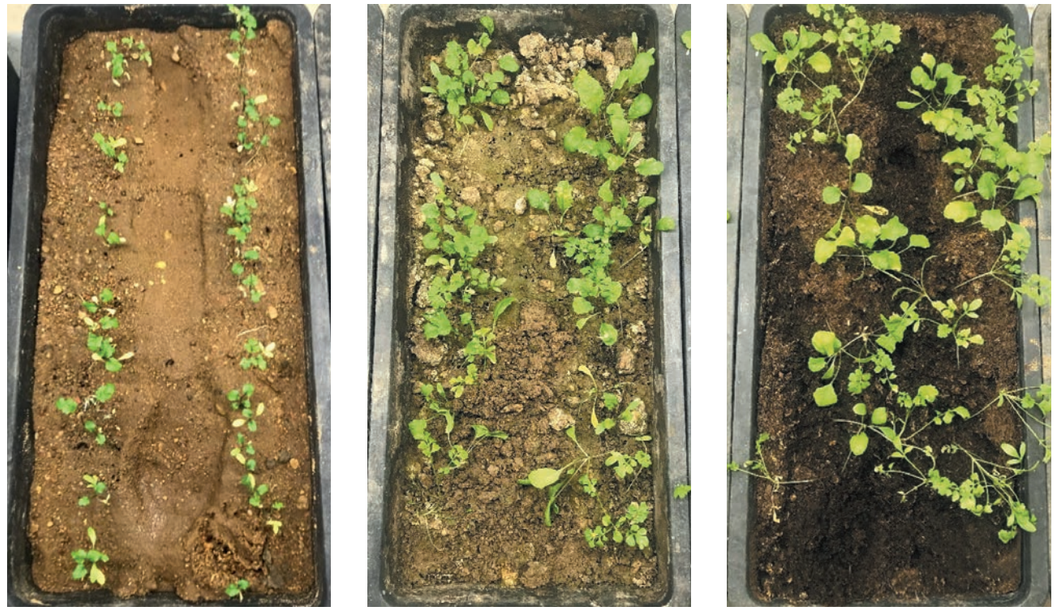
where NPP – net productive photosynthesis, g/m² per day;
V_1, V_2 – first and second plant material samples, g;
L_1, L_2 – leaf area of the first and second samples, m²;
n – period duration, days.

Research Results

The experimental results allowed a comprehensive assessment of the impact from the selected organism association.

Watercress was sown on March 1, 2021; the harvest day was on April 1, 2021 (Figure 2).

The first shoots appeared on March 9, 2021: Sample No. 1 – 40 %; No. 2 – 60 %; No. 3 – 80 %. The total germination percentage was as follows: No. 1 – 75 %; No. 2 – 80 %; No. 3 – 95 %.



No. 1 No. 2 No. 3

Figure 2 – Experimental samples

On March 19, 2021: the phase of three true leaves in Samples No. 2, No. 3 – 100 %; in No. 1 – 50 %.

Figure 3 presents the dynamics of *Lepidium sativum* growth during one month.

Samples No. 2, No. 3 demonstrate a stable plant growth and development; Sample No. 1 showed a decelerated growth since March 22, 2021.

Figure 4 presents a ratio of the numbers of internodes and laminas on the leading shoot at the time of the experiment end.

By both indicators, Sample No. 2 prevails, which is an evidence of an intensive growth and a proof of secondary metabolite accumulation, i.e., the process of active plant development is underway.

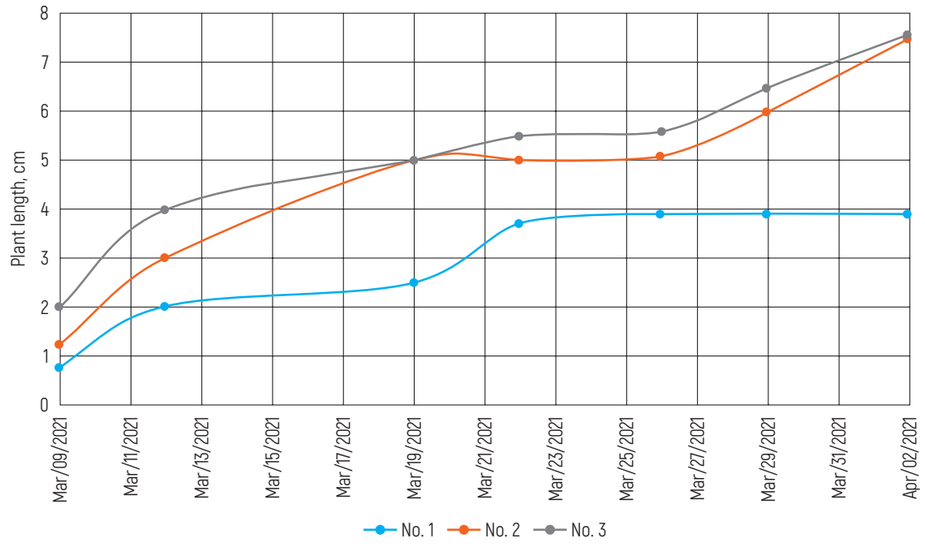


Figure 3 – Dynamics of watercress (*Lepidium sativum*) growth

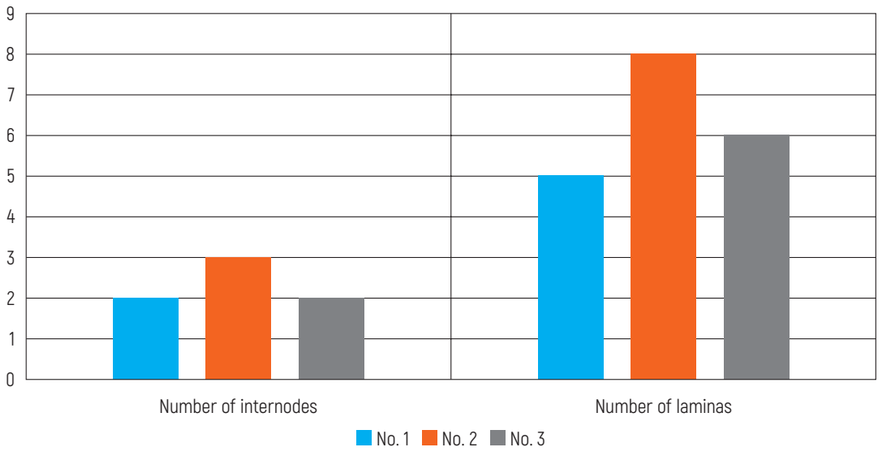


Figure 4 – Ratio of indicators, the number of internodes versus the number of laminas, between samples

Table 1 presents the results of experiments in photosynthesis intensity measurement.

Table 1 – Photosynthesis intensity in the experiments carried out

Experimental variant	Number of bubbles per minute					
	1	2	3	4	5	Average
Clear solution (distilled water), 20 °C						
No. 1 (negative control)	3	3	3	2	2	2.6
No. 2 (association)	12	12	12	10	10	11.2
No. 3 (positive control)	13	12	12	10	10	11.4

During the experiment, we managed to study the intensity of photosynthesis in plants. Besides, the data in Table 1 allows noting that the soil minimum association was able to create conditions for the intensive watercress growth and development by providing it with both mineral nutrients and carbon dioxide. This process is also evidenced by the activity of chlorophyll contained in the leaves (Figure 5).

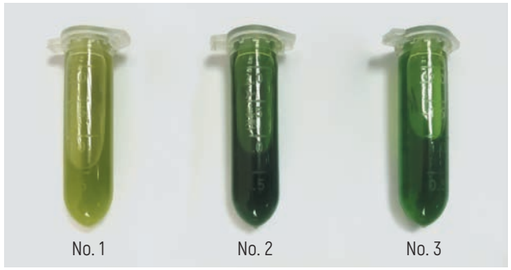


Figure 5 – Chlorophyll extract from the samples

The color saturation of chlorophyll characterizes its amount in the leaves and its activity.

Table 2 shows the net productivity of plants.

Table 2 – Net productivity in the experiment carried out

Experimental variant	Number of plants, pcs	Dry plant mass, g	Leave area of sample one, m^2	Leave area of sample two, m^2	NPP, g/m^2 per day
No. 1 (negative control)	10	1.1	0.004	0.006	7.33
No. 2 (association)	10	15.3	0.004	0.081	12
No. 3 (positive control)	10	15.9	0.004	0.084	12.04

As can be seen, the photosynthesis intensity and watercress net productivity in the variant with the minimum soil association gave a positive result. The experimental samples did not lag behind the sample growth and development in the positive control, as evidenced by their physiological indicators.

The net productivity of plants demonstrates a significant increase in dry biomass, which in turn is an evidence of a balanced *Lepidium sativum* development.

Conclusions and Future Work

The soil fertility restoration is a process of creating a new soil and rejuvenating the old one by minimization of organic matter loss in the upper layer, conservation of more carbon, biodiversity enhancement, maintenance of a proper water and nutrient matter cycle. These factors help reduce the risk of erosion and increase the overall level of soil resilience.

When selecting the minimum association of organisms, the emphasis was made on the accumulation of organic matter and mineral elements in a form accessible to plants or microorganisms. Based on the reference review, an association was selected that was used in the experiment. The obtained results demonstrated that the growth and development indicators of watercress (*Lepidium sativum*) on depleted soil with an introduced organism association were close to the indicators noted in the positive control, that is, they were not inferior to the samples where mineral additives were used. However, it is possible that the trophic connections between new microorganisms were not fully formed in the association; therefore, the effect could be even more significant with a longer coexistence of the association. Besides, there is an additional threat of establishing trophic links between microorganisms introduced and already inhabiting the soil.

In the future, it is planned to conduct an experiment on pure sand with the addition of an already established association of organisms, as well as conducting a longer version of the research.

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UDC 631.427

Fertility and Physico-Chemical Indicators of Light “Space” Potting Soils for EcoCosmoHouse

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While developing soil for an enclosed ecosystem in outer space (in EcoCosmoHouse (ECH)), the authors theoretically substantiated in 2020 a creation of a “space” potting soil consisting of light mineral fillers and an organic part – uTerra humus. In this study, a selection of light mineral (perlite, clay pellets, a mixture of perlite and clay pellets) and organic soil components was made. We studied physico-chemical and agronomic indicators of the presented light “space” potting soils with added biohumus with earthworms *Eisenia andrei*. We had plants bedded out on the new soil, carried out experiments to study the influence of the developed potting soil ingredients on the plant crop growth and development and an analysis of the obtained potting soils agrochemical characteristics. Based on the data obtained, improved compositions of light “space” potting soils have been determined, promising directions for further research are outlined.

Keywords:
macroelements, microelements, soil, universal substrate for plants, potting soil, light potting soil, humus, soil microorganisms, EcoCosmoHouse (ECH), enclosed ecosystem, ecology.

Introduction

The subject matter for the research has been determined by several contemporary preconditions the relevance and significance whereof have been constantly growing lately.

First, the production of plant-based outputs is one of the activities that ensure satisfaction of basic human needs [1].

The quality of life and the level of health of inhabitants on our planet largely depend on the efficiency and environmental friendliness of agriculture in general and crop production in particular [2].

Over the past 100 years, the agro-industrial sector evidenced a start of an active use of mineral fertilizers, pesticides, herbicides, antibiotics, and many other artificially obtained compounds [3]. Their widespread use (despite availability of natural analogs) produces an inevitable negative impact on the quality of plant products that become contaminated in many cases with substances uncharacteristic for living nature. Besides, excessive consumption of various agrochemicals reduces the concentration of humus in the soil, kills soil macro- and microorganisms and thus has a destructive effect on the biosphere of the planet [3–5].

In pursuit of momentary profit and exclusively quantitative indicators, many farmers exceed the rate of applied mineral fertilizers, getting a larger volume of low-quality plant products at some stage. Its low consumer properties are often complemented by a direct threat to human health due to an increased content of nitrates, heavy metals, or other constituents dangerous to humans (some of them can be found in natural food but in disparate quantities) [6, 7].

Second, the development of technology always requires the use of more advanced materials that are superior in their parameters to the previous ones [8]. Taking this point of view to consider innovative environmentally friendly substrates developed for the intensive production of plant products, it is worth noting their main characteristics [9]:

- balance of all macro-, micro- and ultramicroelements;
- proper microbiological composition;
- water capacity;
- breathability;
- lack of harmful admixtures;
- density.

Currently, the decline in the last indicator – density – is becoming still more relevant. While this soil property is not essential for growing crops in the field, it plays an important role in using a specially prepared substrate for plant cultivation when various types of multi-tiered greenhouses, eco-villages with roof gardens, and private biohouses are organized [10]. This feature is due to the following relation: the higher the density of the substrate used, the greater the strength needs to be laid when designing supporting structure for objects, and the more materials will be required, which means the higher the cost of construction will be.

For these reasons, scientists both in our country and abroad are currently investigating actively the issue of creating an easy, yet fertile substrate for bedding out plants that will make it possible to obtain environmentally friendly plant products and, at the same time, will have a rather low density as compared to natural soils [11–14].

In article [15] dealing with the subject matter of light "space" potting soils that would allow minimization of the cost of their delivery to the orbit, possible compositions were considered that could be used in EcoCosmoHouse (ECH). ECH is a part of the Industrial Space Necklace "Orbit" (ISN "Orbit"); it is an enclosed ecosystem located in space and optimized for humans to live and work in comfortable, "terrestrial", conditions [16] (Figure 1).

Besides, article [15] also describes different variants of a mineral part in potting soils; preliminary experiments were carried out that proved the prospects of the direction selected.

The purpose of this work is to check empirically agronomic characteristics of the compiled samples of light "space" potting soils that are supposed to be used as a substrate for growing plants in ECH. The study must be carried out with an understanding of the following: a multimeter soil layer in ECH should provide, among other things, two important functions, namely antimeteorite and antiradiation protection of lives inside the enclosed ecosystem of the orbital house, including humans.

This article presents indicators of plant growth and development measurements and the results of agrochemical analyzes; it also suggests new compositions for "space" potting soils.

Research Methods

In the course of the experiment, the elemental composition of potting soils was monitored, using the technical normative regulations to analyze the following characteristics:

- humidity level – GOST 26268-89;
- ash content level – STB 2042-2010;
- pH level – STB 17.13.05-36-2015;
- potassium content – GOST 26207-91;
- total nitrogen content – GOST 26715-85;
- nitrate nitrogen content in sand soils – STB 17.13.05-28-2014;
- nitrate nitrogen content in peats – GOST 27894.4-88;
- phosphorus content – GOST 26207-91.

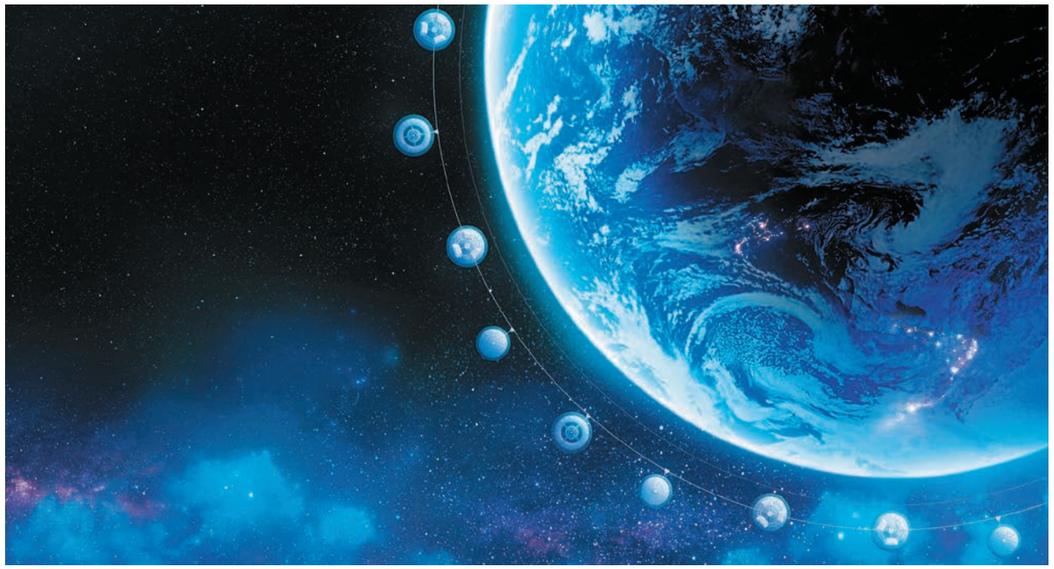

Figure 1 – ISN "Orbit" visualization [17]

Experimental Procedure

In 2019–2020, three compositions of light potting soils were designed, plants were selected, and an experiment was commenced to determine agronomic properties of the compositions. The starting date of the new study was February 1, 2021: three out of four plants were set out on every seedbed in the top tier.

Composition No. 1 by volume: 90 % clay pellets + 5 % uTerra humus + 5 % biohumus (Figure 2).

Composition No. 2 by volume: 45 % clay pellets + 45 % perlite + 5 % uTerra humus + 5 % biohumus (Figure 3).

Composition No. 3 by volume: 90 % perlite + 5 % uTerra humus + 5 % biohumus (Figure 4).

During the experiment (Figure 5), a layer of biohumus circa 5 cm thick was put to the upper part of the experimental seedbeds (one month after setting out the plants), and red Californian earthworms were introduced at a rate of 2×10^6 per 1 ha of the area.

Figure 2 – Plants that were bedded out using Composition No. 1.
Top tier: lemon, lime, cumquat, plantain;
bottom tier: mint, thyme, rosemary

Figure 4 – Plants that were bedded out using Composition No. 3.
Top tier: mandarin, lime, cumquat, laurel;
bottom tier: mint, thyme, rosemary

Figure 3 – Plants that were bedded out using Composition No. 2.
Top tier: mandarin, lime, cumquat;
bottom tier: mint, thyme, rosemary

Figure 5 – General view of seedbeds
with light "space" potting soils

Dynamics of Plant Growth

In the course of the study, the growth parameters were measured, and the temperature and humidity in the room were monitored. A summary is presented in Table 1.

Detailed data is summarized in Table 2.

The average room temperature during the period between February 1, 2021 and April 5, 2021 was 22.44 °C (fixed twice per week).

The average room humidity during the period between February 1, 2021 and April 5, 2021 was 31 % (fixed twice per week).

Table 1 – Physiological indicators of plants

Plant	Control period	Height growth, cm	Number of shoots, pcs	Shoot length gain, cm	Number of fresh leaves, pcs	Average fresh leaf length, cm
Composition No. 1						
Lemon	Feb/01/2021 – Apr/05/2021	10	22.25	3.8	3	4
Lime	Feb/01/2021 – Apr/05/2021	9	20.85	4.9	4	7.4
Cumquat	Feb/01/2021 – Apr/05/2021	16	17.55	3.9	2	6.6
Plantain*	Apr/08/2021 – Apr/30/2021	10	–	–	2	10
Composition No. 2						
Mandarin	Feb/01/2021 – Apr/05/2021	6	25.6	3.6	4	2.8
Lime	Feb/01/2021 – Apr/05/2021	12	14.25	6.7	5	5.6
Cumquat	Feb/01/2021 – Apr/05/2021	3	1.55	2.1	2	1.8
Composition No. 3						
Mandarin	Feb/01/2021 – Apr/05/2021	9	29.8	9.1	2	6.4
Lime	Feb/01/2021 – Apr/05/2021	8	25.8	5.1	3	2.2
Cumquat	Feb/01/2021 – Apr/05/2021	8	13.8	2.9	2	2.3
Laurel*	Mar/12/2021 – Apr/05/2021	5	9.2	1.8	2	1.4

* Plantain and laurel were planted later.

Table 2 – Plant growth gain on the seedbeds with experimental light "space" potting soils

Date	Plant height, cm	Number of shoots, pcs	Shoot length, cm	Number of fresh leaves, pcs	Average fresh leaf length, cm	Room temperature, °C	Humidity, %
1	2	3	4	5	6	7	8
Lemon (Composition No. 1)							
Feb/01/2021	40	18	16	9	6	21.7	39
Feb/05/2021	40	18	16	9	6.3	21.9	39
Feb/08/2021	41	18	16.5	9	6.9	20.8	40
Feb/12/2021	41	20	16.5	9	7.2	21.2	40
Feb/15/2021	43	20	17	9	7.8	20.8	40
Feb/19/2021	44	22	17	10	8.5	20.6	40

Continuation of Table 2

1	2	3	4	5	6	7	8
Feb/22/2021	46	22	17.5	10	8.7	21.8	41
Feb/26/2021	47	22	17.5	10	8.8	22.1	41
Mar/01/2021	48	22	18	10	9	21.9	41
Mar/05/2021	48	22	18.1	11	9.5	23	23
Mar/09/2021	48	23	18.3	11	9.5	23.4	24
Mar/13/2021	48	23	18.4	11	9.6	23.1	23
Mar/15/2021	49	23	18.6	11	9.6	23.6	25
Mar/17/2021	49	24	18.7	11	9.7	24.1	23
Mar/19/2021	49	24	18.8	12	9.7	22.8	24
Mar/22/2021	49	24	19	12	9.7	23.2	26
Mar/26/2021	49	25	19.1	12	9.8	23.4	23
Mar/29/2021	50	25	19.3	12	9.9	23.4	22
Apr/02/2021	50	25	19.5	12	9.9	22.7	23
Apr/05/2021	50	25	19.8	12	10	23.3	23
Lime (Composition No. 1)							
Feb/01/2021	81	15	5	3	3	21.7	39
Feb/05/2021	81	15	5	3	3.5	21.9	39
Feb/08/2021	82	17	5.5	3	3.9	20.8	40
Feb/12/2021	82	17	5.5	3	4.6	21.2	40
Feb/15/2021	83	19	6	4	5.4	20.8	40
Feb/19/2021	84	20	6.5	4	6.8	20.6	40
Feb/22/2021	84	20	7	4	7.6	21.8	41
Feb/26/2021	85	21	7.5	4	9	22.1	41
Mar/01/2021	86	21	8	4	9.2	21.9	41
Mar/05/2021	86	21	8.2	4	9.7	23	23
Mar/09/2021	86	21	8.5	5	10	23.4	24
Mar/13/2021	87	21	8.7	6	10	23.1	23
Mar/15/2021	87	22	8.9	6	10	23.6	25
Mar/17/2021	87	23	8.9	6	10.1	24.1	23
Mar/19/2021	88	24	9	6	10.2	22.8	24
Mar/22/2021	89	24	9.2	6	10.3	23.2	26
Mar/26/2021	89	24	9.4	7	10.3	23.4	23
Mar/29/2021	89	24	9.6	7	10.4	23.4	22

Continuation of Table 2

1	2	3	4	5	6	7	8
Apr/02/2021	90	24	9.8	7	10.4	22.7	23
Apr/05/2021	90	24	9.9	7	10.4	23.3	23
Cumquat (Composition No. 1)							
Feb/01/2021	62	2	4	4	1.2	21.7	39
Feb/05/2021	62	2	4	4	1.5	21.9	39
Feb/08/2021	63	6	4.5	4	2	20.8	40
Feb/12/2021	65	10	4.5	4	2.6	21.2	40
Feb/15/2021	68	12	5	5	3.4	20.8	40
Feb/19/2021	70	15	5.5	5	4.6	20.6	40
Feb/22/2021	71	20	6	5	5.8	21.8	41
Feb/26/2021	73	21	6.5	5	6.2	22.1	41
Mar/01/2021	75	21	7	5	7	21.9	41
Mar/05/2021	76	22	7.2	5	7.4	23	23
Mar/09/2021	76	22	7.3	5	7.4	23.4	24
Mar/13/2021	76	22	7.3	5	7.5	23.1	23
Mar/15/2021	76	22	7.5	5	7.6	23.6	25
Mar/17/2021	76	22	7.5	5	7.6	24.1	23
Mar/19/2021	76	22	7.6	5	7.7	22.8	24
Mar/22/2021	77	22	7.6	5	7.7	23.2	26
Mar/26/2021	77	22	7.7	6	7.7	23.4	23
Mar/29/2021	78	22	7.7	6	7.8	23.4	22
Apr/02/2021	78	22	7.8	6	7.8	22.7	23
Apr/05/2021	78	22	7.9	6	7.8	23.3	23
Plantain (Composition No. 1)							
Apr/08/2021	30	–	–	6	21	23.3	23
Apr/12/2021	30	–	–	6	21	23.3	23
Apr/16/2021	31	–	–	6	23	23.3	23
Apr/19/2021	33	–	–	7	26	23.3	23
Apr/23/2021	36	–	–	7	29	23.3	23
Apr/26/2021	39	–	–	8	31	23.3	23
Apr/30/2021	40	–	–	8	33	23.3	23
Mandarin (Composition No. 2)							
Feb/01/2021	64	20	2	4	2.7	21.7	39

Continuation of Table 2

1	2	3	4	5	6	7	8
Feb/05/2021	64	20	2	4	2.9	21.9	39
Feb/08/2021	64	20	2.5	5	3.2	20.8	40
Feb/12/2021	65	23	2.5	5	3.3	21.2	40
Feb/15/2021	65	23	2.5	5	3.4	20.8	40
Feb/19/2021	65	23	3	5	3.6	20.6	40
Feb/22/2021	65	26	3	6	3.8	21.8	41
Feb/26/2021	66	26	3	6	3.9	22.1	41
Mar/01/2021	66	26	3.5	6	4	21.9	41
Mar/05/2021	66	27	3.6	6	4.1	23	23
Mar/09/2021	66	27	3.8	7	4.2	23.4	24
Mar/13/2021	67	27	3.9	7	4.3	23.1	23
Mar/15/2021	67	27	4	7	4.5	23.6	25
Mar/17/2021	67	27	4.3	7	4.7	24.1	23
Mar/19/2021	68	28	4.6	7	4.8	22.8	24
Mar/22/2021	68	28	4.9	7	4.9	23.2	26
Mar/26/2021	68	28	5	8	5	23.4	23
Mar/29/2021	69	28	5.2	8	5.2	23.4	22
Apr/02/2021	69	29	5.4	8	5.3	22.7	23
Apr/05/2021	70	29	5.6	8	5.5	23.3	23
Lime (Composition No. 2)							
Feb/01/2021	66	11	12	5	6	21.7	39
Feb/05/2021	67	11	12	5	6.5	21.9	39
Feb/08/2021	68	11	12.5	6	7.2	20.8	40
Feb/12/2021	69	12	13	6	7.8	21.2	40
Feb/15/2021	70	12	13.5	7	8.5	20.8	40
Feb/19/2021	71	14	13.5	7	9.2	20.6	40
Feb/22/2021	72	14	14.5	8	9.5	21.8	41
Feb/26/2021	73	14	15	8	9.8	22.1	41
Mar/01/2021	75	14	16	8	10.2	21.9	41
Mar/05/2021	75	14	17.2	8	10.8	23	23
Mar/09/2021	75	14	17.4	8	10.9	23.4	24
Mar/13/2021	76	14	17.6	8	10.9	23.1	23
Mar/15/2021	76	14	17.7	8	10.9	23.6	25

Continuation of Table 2

1	2	3	4	5	6	7	8
Mar/17/2021	76	15	17.9	9	11	24.1	23
Mar/19/2021	76	16	18.2	9	11.2	22.8	24
Mar/22/2021	77	16	18.3	9	11.2	23.2	26
Mar/26/2021	77	16	18.5	9	11.2	23.4	23
Mar/29/2021	77	17	18.6	9	11.4	23.4	22
Apr/02/2021	78	18	18.7	10	11.5	22.7	23
Apr/05/2021	78	18	18.7	10	11.6	23.3	23
Cumquat (Composition No. 2)							
Feb/01/2021	60	1	1	3	2.8	21.7	39
Feb/05/2021	60	1	1	3	3	21.9	39
Feb/08/2021	60	1	1.5	3	3.1	20.8	40
Feb/12/2021	60	1	1.5	3	3.3	21.2	40
Feb/15/2021	60	1	1.5	4	3.5	20.8	40
Feb/19/2021	60	1	1.5	4	3.7	20.6	40
Feb/22/2021	61	1	2	4	3.8	21.8	41
Feb/26/2021	61	1	2	4	3.9	22.1	41
Mar/01/2021	61	1	2.5	4	4	21.9	41
Mar/05/2021	61	1	2.5	4	4.1	23	23
Mar/09/2021	61	1	2.5	4	4.1	23.4	24
Mar/13/2021	61	1	2.5	4	4.1	23.1	23
Mar/15/2021	61	1	2.6	4	4.2	23.6	25
Mar/17/2021	61	1	2.6	4	4.3	24.1	23
Mar/19/2021	61	1	2.7	4	4.3	22.8	24
Mar/22/2021	61	2	2.9	4	4.4	23.2	26
Mar/26/2021	62	3	2.9	4	4.4	23.4	23
Mar/29/2021	62	3	3	4	4.5	23.4	22
Apr/02/2021	63	4	3	5	4.6	22.7	23
Apr/05/2021	63	4	3.1	5	4.6	23.3	23
Mandarin (Composition No. 3)							
Feb/01/2021	74	27	5	7	3.6	21.7	39
Feb/05/2021	74	27	5	7	3.8	21.9	39
Feb/08/2021	74	29	5.5	7	4	20.8	40
Feb/12/2021	74	29	5.5	7	4.2	21.2	40

Continuation of Table 2

1	2	3	4	5	6	7	8
Feb/15/2021	75	32	5.5	7	4.5	20.8	40
Feb/19/2021	75	32	6	7	4.6	20.6	40
Feb/22/2021	76	34	6	8	4.8	21.8	41
Feb/26/2021	76	34	6	8	4.9	22.1	41
Mar/01/2021	77	34	6.5	8	5	21.9	41
Mar/05/2021	77	35	6.8	8	5	23	23
Mar/09/2021	77	35	7	8	5.2	23.4	24
Mar/13/2021	79	27*	12.8	8	9.4	23.1	23
Mar/15/2021	79	27	13	8	9.6	23.6	25
Mar/17/2021	80	27	13.2	9	9.7	24.1	23
Mar/19/2021	80	27	13.5	9	9.9	22.8	24
Mar/22/2021	81	28	13.6	9	9.9	23.2	26
Mar/26/2021	81	28	13.7	9	9.9	23.4	23
Mar/29/2021	82	28	13.8	9	9.9	23.4	22
Apr/02/2021	82	28	14	9	10	22.7	23
Apr/05/2021	83	28	14.1	9	10	23.3	23
Lime (Composition No. 3)							
Feb/01/2021	75	20	9	6	7.8	21.7	39
Feb/05/2021	75	20	9.5	6	8	21.9	39
Feb/08/2021	75	22	9.5	6	8.1	20.8	40
Feb/12/2021	76	22	10	7	8.2	21.2	40
Feb/15/2021	76	23	10.5	7	8.5	20.8	40
Feb/19/2021	77	26	11	7	8.7	20.6	40
Feb/22/2021	78	26	11	8	8.8	21.8	41
Feb/26/2021	78	27	11.5	8	9	22.1	41
Mar/01/2021	79	27	12	8	9.1	21.9	41
Mar/05/2021	79	27	12.4	8	9.2	23	23
Mar/09/2021	79	27	12.7	8	9.4	23.4	24
Mar/13/2021	79	27	12.8	8	9.4	23.1	23
Mar/15/2021	79	27	13	8	9.6	23.6	25
Mar/17/2021	80	27	13.2	9	9.7	24.1	23
Mar/19/2021	80	27	13.5	9	9.9	22.8	24

* Pruning of shoots was carried out.

Continuation of Table 2

1	2	3	4	5	6	7	8
Mar/22/2021	81	28	13.6	9	9.9	23.2	26
Mar/26/2021	81	28	13.7	9	9.9	23.4	23
Mar/29/2021	82	28	13.8	9	9.9	23.4	22
Apr/02/2021	82	28	14	9	10	22.7	23
Apr/05/2021	83	28	14.1	9	10	23.3	23
Cumquat (Composition No. 3)							
Feb/01/2021	61	3	2	4	4.3	21.7	39
Feb/05/2021	61	3	2	4	4.5	21.9	39
Feb/08/2021	61	6	2	4	4.7	20.8	40
Feb/12/2021	62	7	2.5	4	4.9	21.2	40
Feb/15/2021	62	13	2.5	4	5	20.8	40
Feb/19/2021	63	13	3	4	5.2	20.6	40
Feb/22/2021	64	14	3.5	5	5.4	21.8	41
Feb/26/2021	66	16	3.5	5	5.6	22.1	41
Mar/01/2021	67	16	4	5	5.9	21.9	41
Mar/05/2021	67	17	4.3	5	6.3	23	23
Mar/09/2021	67	17	4.4	5	6.4	23.4	24
Mar/13/2021	67	16*	4.4	5	6.4	23.1	23
Mar/15/2021	67	16	4.5	5	6.4	23.6	25
Mar/17/2021	68	16	4.5	5	6.4	24.1	23
Mar/19/2021	68	16	4.6	5	6.4	22.8	24
Mar/22/2021	68	17	4.6	5	6.5	23.2	26
Mar/26/2021	69	17	4.7	5	6.5	23.4	23
Mar/29/2021	69	17	4.8	5	6.5	23.4	22
Apr/02/2021	69	18	4.8	6	6.5	22.7	23
Apr/05/2021	69	18	4.9	6	6.6	23.3	23
Laurel (Composition No. 3)							
Mar/12/2021	62	19	9.5	5	6.5	23.1	23
Mar/15/2021	62	19	9.7	5	6.6	23.6	25
Mar/17/2021	63	20	10	5	6.8	24.1	23
Mar/19/2021	63	20	10.2	6	6.9	22.8	24
Mar/22/2021	64	20	10.4	6	7.1	23.2	26

* Pruning of shoots was carried out.

End of Table 2

1	2	3	4	5	6	7	8
Mar/26/2021	65	21	10.6	6	7.3	23.4	23
Mar/29/2021	66	21	10.9	6	7.5	23.4	22
Apr/02/2021	66	21	11.1	7	7.7	22.7	23
Apr/05/2021	67	22	11.3	7	7.9	23.3	23

At the initial stage of the study, the influence of a particular potting soil on the growth and development of selected crops differs insignificantly. In this experiment, active vegetation is inherent in all types of shrub and woody plants, spicy aromatic herbs, and plantain. According to the results obtained, the growth of shoots on all plants occurs at approximately the same level.

As an illustrative example, indicators for acidic lime (*Citrus* × *Aurantiifolia* (Christm.) Swingle) are chosen, as it is present in all potting soil options. The plant demonstrated the following growth dynamics (Figure 6).

It is evident from the diagram in Figure 6 that all lime specimens in the study demonstrate a so-called stage IV – a stationary development state that indicates the beginning of a growing season in woody crops.

Plant growth indicators explicitly reflect a physiological activity of enzymes and phytohormones in organisms [18]. Usually, establishing a growth rate at the same level indicates a presence of aging plants or (in case of perennial plants) the beginning of a transition to a reproduction (blossoming) stage [19].

An active life of plants is favored by earthworms inhabited in the experimental seedbeds and small soil insects living in the potting soil that process the organic matter already existing and returned to the soil (dry leaves, stems, and dying roots) into humus [20]. After three months of the study, the activity of earthworms was also observed.

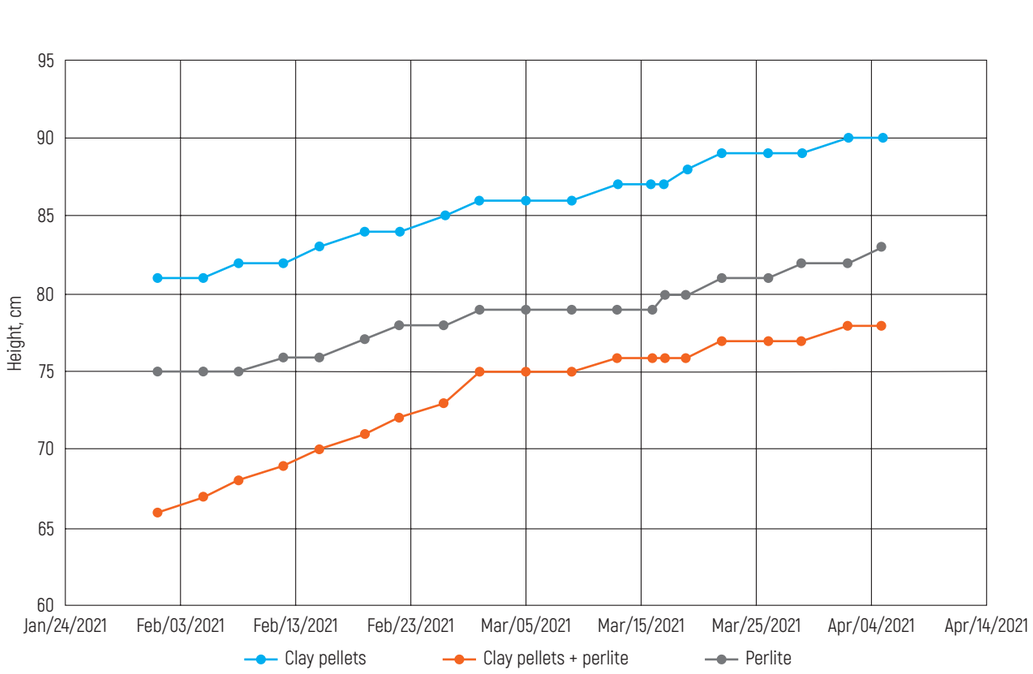

Figure 6 – Growth dynamics of acidic lime (*Citrus* × *Aurantiifolia* (Christm.) Swingle)

Chemical Studies of Light "Space" Potting Soils

To study changes in the composition of light "space" potting soils, chemical analyzes were carried out. Samples were taken before laying the potting soils in the seedbeds and after three months. The results of agrochemical tests are presented in Table 3.

The data obtained allow the following assumptions on agrochemical and microbiological processes occurring in the potting soils under consideration.

The ash content in all samples decreases, while the amount of macronutrients and humic acids increases. Such changes evidence an active work of microorganisms that use the mineral part of light "space" potting soils in their vital activities, and, consequently, an inclusion of minerals in the circulation of elements and energy in the biosphere [21, 22].

The highest content of nutrients and their maximum quantitative increase is observed in Composition No. 3. On the one hand, this may indicate a significant initial content of nutrients, the growth rate of microorganisms, and a higher value of the potting soil [23]. On the other hand, this fact evidences that perlite, due to its sorption capacity, retains too many nutrients and releases them rather slowly [24]. The acidity index is within an optimal range for all

Table 3 – Results of agrochemical analyzes on experimental samples of light "space" potting soils

Composition	Ash content, %	pH	Potassium oxide, mg/100 g	Phosphates, mg/100 g	Nitrates, mg/100 g	Total nitrogen, %	Humic acids, %
Before planting							
Composition No. 1	90.63	6	52.1	27.3	17.5	0.19	11.08
Composition No. 2	90.71	5.9	54.71	28.4	29.4	0.3	10.8
Composition No. 3	91.12	6.8	128.1	56.8	64.1	0.35	11.3
Three months after planting							
Composition No. 1	87.92	6.3	76.2	49.8	30	0.16	12.58
Composition No. 2	86.67	6.3	147.6	64.2	95	0.31	11.95
Composition No. 3	87.4	6.5	274.9	119	165	0.53	12.41

compositions and does not change dramatically, thereby confirming the system stability [25]. A significant relative increase in the concentration of macroelements can be traced in Composition No. 2, which supposes more intensive agrochemical and microbiological processes in it.

A New Experiment Taking into Account the Data Obtained

Upon analyzing the data obtained, the authors concluded that other raw materials should be also used for a more profound research. To understand thoroughly the essence of biological and chemical processes occurring in light "space" potting soils, it is necessary to study their components in various (qualitative and fractional) ratios.

Based on the information obtained, it is possible to achieve the best agronomic qualities of the product being developed by combining options of different qualitative and fractional composition (the contents of macro- and micronutrients, presence of agronomically valuable microorganisms, ability to retain and release humidity, etc.), while keeping its least density.

Table 4 presents new elaborated compositions.

Table 4 – Extended compositions of light "space" potting soils

Component denomination and their ratio by volume	Potting soil volume, l	Number of organic components	Obtained composition density, t/m^3
1. Perlite 0.16–3 mm	1	Biohumus 50 g uTerra humus 50 g	0.142
2. Clay pellets 1–3 mm	1	Biohumus 50 g uTerra humus 50 g	0.505
3. Perlite 0.16–3 mm + clay pellets 1–3 mm (2 : 1)	1	Biohumus 50 g uTerra humus 50 g	0.263
4. Perlite 0.16–5 mm + clay pellets 1–5 mm (2 : 1)	1	Biohumus 50 g uTerra humus 50 g	0.24
5. Layering in the ratio of 4 : 1: • perlite 0.16–5 mm (on the top) • clay pellets 1–5 mm (at the bottom)	1	Biohumus 50 g uTerra humus 50 g	0.198

Figure 7 presents the compositions with planted mint. It should be noted: the roots go to the bottom, i.e., the plants have taken root and are actively vegetating.

Figure 7 – New compositions of light "space" potting soils

Conclusions and Future Work

All plants bedded out on the light "space" potting soils (lemon, plantain, mandarin, lime, cumquat, laurel, mint, thyme, rosemary) easily take roots, grow fast, look healthy, and have a deep green color, they are characterized by a usual minimum of dying leaves. The agrochemical tests evidence that the content of nutrients in the light "space" potting soils is at a high level.

Earthworms, as well as small soil insects, actively live and proliferate in the seedbeds. This indicates at biological processes running intensively in the designed light "space" potting soils, including decomposition of organic matter (leaves, dry branches, etc.) and its subsequent return into a biological cycle.

With the positive dynamics of plant growth and agrochemical indicators of light "space" potting soils taken into account, the authors believe that the selected substrates are optimal for growing not only fruit trees (citrus cultures in this study), aromatic herbs, and plantain but also leaf cultures, vegetables, and other plants with similar requirements to the soil.

Upon analyzing the information on the growth indices of the planted crops, it can be argued that the plants have taken root and grow intensively on all light "space" potting soils, and differences in the data obtained for different compositions can be due to individual characteristics of plant organisms. Such a result is explained by a suitable microbiome and a good nutritional balance of the compositions under research where biohumus and uTerra humus produced from brown coal are used as their organic part.

To determine the optimal formulation, it is necessary to test the new potting soils mentioned in the article. Besides, an analysis of technical and economic characteristics should be carried out for all presented potting soils. Thus, ideal compositions of light "space" potting soils will be determined, which will allow to grow high-quality, healthy eco-products in ECH and have a minimum weight that helps to reduce the cost of their delivery to orbit.

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UDC 579.695

Role of Methanogenic Archaebacteria in Processing of Organic Waste in an Enclosed Ecosystem

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The article reviews a group of methanogenic bacteria belonging to the *Archaea* domain, which allows for the complete processing of organic waste without the use of oxygen. The influence of the vital activity of methanogens in an enclosed ecosystem has been studied: anaerobic processing of organic matter, assimilation of inhibitor metabolites, reduction of organic mass during its recycling, as well as minimization of possible negative effects – the release of methane and other gases (carbon dioxide, ammonia, hydrogen sulfide, hydrogen). A method of refining generated gases is proposed.

Keywords:
archaebacteria, methanogenic bacteria, waste biodegradation, biofilter, methanotrophs, enclosed ecosystem, EcoCosmoHouse (ECH).

Introduction

Living outside the Earth is a difficult task, and to solve it, it is important to build a bioregenerative life support system – an enclosed artificial ecosystem based on ecological principles, in which oxygen, water, and basic food sources are processed using biotechnologies. Consequently, the creation of a microenvironment similar to the terrestrial one [1] would solve the issues of life support systems at space stations, as well as in sealed domes or bunkers to preserve the human population in cases of significant deterioration of environmental parameters that do not allow people to exist openly on the surface of a planet [2].

Experiments on enclosed ecosystems were conducted in the USA (Biosphere-2), China (Lunar Palace-1), as well as at the Krasnoyarsk Institute of Biophysics of the former USSR (currently Biophysics Institute of the Siberian Branch of the RAS). The most successful results were obtained in Krasnoyarsk. Soviet scientists have developed experimental complexes BIOS-1, BIOS-2, BIOS-3, in which the test persons managed to live for more than six months without consuming oxygen from the external environment [3]. The entire circulation of oxygen and carbon dioxide was looped thanks to photosynthetic plants and algae. In addition, in the enclosed system, the need for carbohydrates, water, and oxygen for breathing was also replenished. However, the processing of organic waste was carried out by physical and chemical methods – dissolution in acid, mineralization, neutralization of salts, introduction of salts into the soil for plant cultivation [4]. Canned meat stored at the beginning of the experiment was also used for protein nutrition of the crew.

When creating EcoCosmoHouse (ECH) [2], the processing of organic waste should be carried out by biological methods – without the use of non-natural technologies. The obvious problem of enclosed life support systems is oxygen consumption during aerobic decomposition of organic waste. The fact is that anaerobic decomposition of organic matter (fermentation) from the point of view of biotechnology is associated with a number of difficulties, such as the release of toxic gases, frequent stoppage of fermentation processes, and preservation of microorganisms due to the accumulation of organic acids and alcohols. The decomposition process can be accelerated if archaebacteria are introduced into the system as a ferment.

Archaebacteria are isolated into a separate kingdom due to the fact that a large number of differences from other groups of microorganisms have been found in them [5, 6]. Archaea include various types of organisms that can exist under ultimate conditions at extremely high temperatures (thermophiles), pH (acidophiles), salinity (halophilic bacteria). In addition, archaea include such species as methane-producing (methanogenic) and sulfur-reducing bacteria [7, 8].

All known species of methanogenic bacteria belong to this kingdom. They use fermentation products of other bacteria in their vital activity, as a result of which methane and some other gases (CO_2, ammonia, hydrogen sulfide, hydrogen) are released. Thanks to the activity of methanogenic bacteria, almost complete processing of organic waste occurs, humus is formed without dangerous pathogens, fertile and useful for plants.

Of these groups of microorganisms, methanogenic bacteria are of the greatest practical interest from the point of view of the ECH functioning, allowing for complete oxygen-free decomposition of organic waste arising in the process of human, animal, and plant life.

Currently, the technology of using the ability of microorganisms to process and neutralize organic pollutants in wastewater treatment systems has become widespread. The Table shows the comparative characteristics of aerobic and anaerobic refining [9].

Table – Comparison of indicators
of aerobic and anaerobic wastewater treatment [9]

Aerobic process	Anaerobic process
High energy expenditure on aeration	No aeration is required (the energy consumption of the anaerobic process is 10 times lower than that of the aerobic one)
Dilution of concentrated effluents is required	It is possible to clean highly concentrated effluents
Formation of a significant amount of activated slime biomass (1–1.5 kg per 1 kg of decomposed contaminants)	A small increase in the biomass of activated slime (0.1–0.2 kg per 1 kg of decomposed contaminants)
High oxygen consumption	Oxygen is consumed only at the initial stages of biodegradation from degradable substrate

The formation of methane during anaerobic degradation is a complex process that can be divided into four phases: hydrolysis, acidogenesis, acetogenesis, and methanogenesis [10]. The stages of degradation are carried out by different consortia, partially located in a syntactic relationship and imposing certain requirements on the environment. The first group of microorganisms consists of hydrolytic bacteria. They hydrolyze polymer materials to monomers by extracellular hydrolytic enzymes (cellulases, xylanases, amylases, proteases, lipases).

Most bacteria are strict anaerobes, such as bacteroids, clostridia, and bifidobacteria. In addition, some facultative anaerobes – *Streptococci* and *Enterobacteriaceae* – take part in it. The second group of microorganisms are acidogenic bacteria. They convert sugars and amino acids into carbon dioxide, hydrogen, ammonia, and other organic acids. The third group includes acetogenic bacteria. Higher volatile fatty acids are converted into acetic acid and hydrogen by obligate acetogenic bacteria. Typical homoacetogenic bacteria are *Acetobacterium woodii* and *Clostridium aceticum*. At the end of the decomposition process, two groups of methanogenic bacteria produce methane from acetic acid or hydrogen and carbon dioxide. These bacteria are strict anaerobes and require a lower redox potential for growth than most other anaerobic bacteria. Only a few species are able to decompose acetic acid to methane and carbon dioxide, for example, *Methanosarcina barkeri*, *Methanococcus mazei*, and *Methanothrix soehngenii* [11].

The main purpose of the research is to study the presence of archaebacteria, and, if necessary, their introduction into the wastewater treatment plant located in the collector of house No. 12 at the Unitsky's Farm Enterprise in the town of Maryina Gorka, as well as to assess the possible risks of using this group of microorganisms in an enclosed ecosystem. The collector of house No. 12 was created as a model wastewater treatment system (in the future, it is planned to use a pilot design in ECH). This research will allow to study the possibility of creating a system for wastewater treatment in an enclosed ecosystem.

Description of the Research Method

Cultivation of Archaebacteria

Archaebacteria are difficult to cultivate in the laboratory. For their introduction into the collector at home, it is necessary to build a special plant for the development of the culture. The simplest such equipment can be made with a polymer sealed barrel for 30–50 l.

An approximate scheme is shown in Figure 1. In advance, there should be provided the possibility for the action of a bacterial association that prepares the substrate for methanogens (oxidation, fermentation).

Methanogenic microorganisms are always present in the intestinal tract of cattle as an important component of endosymbionts. That is why the exometabolites of these animals contain a significant number of methanogens. In the pilot plant shown in Figure 1, a mixture of water and manure is laid in a ratio of 1 : 1. At the end of the anaerobic fermentation, the process of methanogenesis is started, which is characterized by rapid release of biogas. From this moment on, there is a sufficient amount of methanogenic bacteria in the active state in the mixture and it is possible to introduce them into the reservoir of the collector as an inoculum.

The following steps should be observed to cultivate archaebacteria in the installation.

1. Select microorganisms or obtain them in the collection.

2. Cultivate under conditions that simulate the environment [12].

When creating the conditions, it is necessary to set the parameters of the environment from which the microorganisms were selected. Such characteristics include the corresponding physical and chemical parameters, the required sources of metabolic energy, nutrients, and microelements (for example, vitamins, organic compounds, soil leaching fluids or cell extract). To eliminate microbial pollutants and increase the efficiency of cultivation of some archaea, other additives are included (in particular, specific antibiotics such as kanamycin and streptomycin, which inhibit bacterial growth [13, 14], as well as fungal inhibitors – nystatin or azoxystrobin [15, 16]). All components of the medium are supplied in appropriate concentrations to maintain the monitored growth during cultivation.

3. Incubate microorganisms in an isolated anaerobic chamber.

The total number of collector microorganisms was studied in the article [17]. Currently, samples of wastewater from house No. 12 in the Unitsky's Farm Enterprise have been collected to analyze the presence of archaebacteria. In addition, it is necessary to plan the creation of an installation for the further cultivation of this group of microorganisms.

After the suspension of methanogenic bacteria has been developed, it is introduced into the collector of the house in order to conduct an experiment on wastewater disposal.

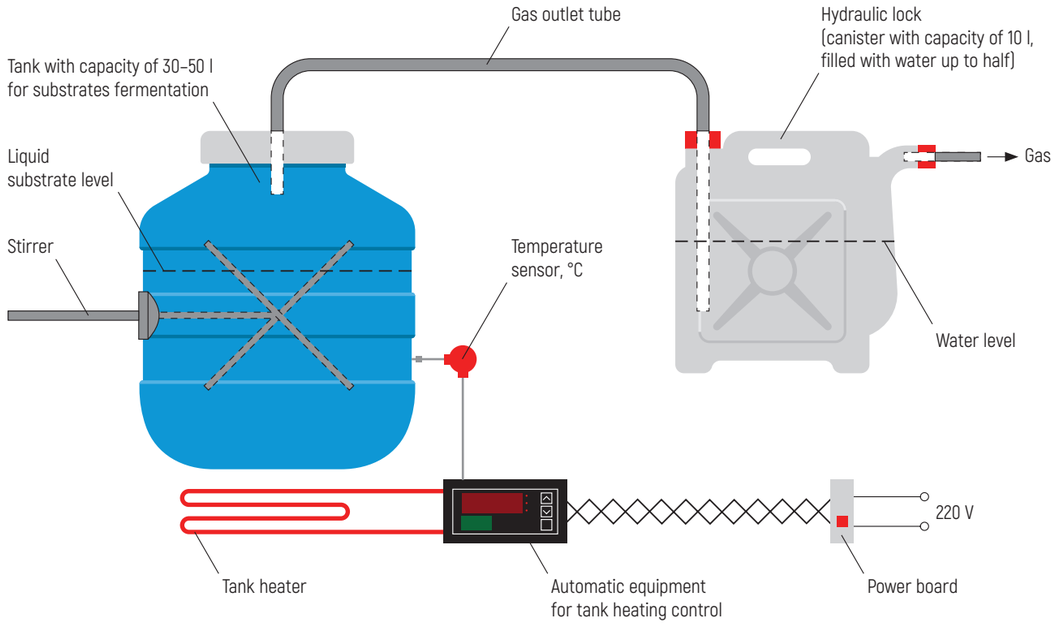


Figure 1 – Diagram of a plant for cultivation of methanogenic archaebacteria

Setting Up an Experiment

The experiment on the vital activity of archaebacteria takes place under the conditions of an underground collector (Figure 2), created under house No. 12 on the basis of Unitsky's Farm Enterprise. This type of structure can be referred to the installation of anaerobic wastewater treatment. In the previous experiment, the total number of microorganisms living in the collector was determined using the same equipment [17].

This structure is a reservoir with walls permeable to the roots of plants. Its main role is to collect drains from toilets and kitchen of the house, as well as filtration of contaminated liquid through layers of organic matter. There occurs mineralization of substances in the collector (due to the action of microorganisms) and the release of macro- and microelements into the soil, where they can be absorbed by plant roots.

The samples were left at 20 °C temperature, typical for sewage collector. However, no gas formation was noticed during the month of observations. At the same time, repeated counting of the total number of microorganisms showed its further decrease in samples from 1×10^7 CFU/ml to 1×10^5 CFU/ml, which indicates the death of microorganisms due to the low content of nutrients in the studied water.

The data obtained indicate the probable absence of methanogens in the collector reservoir. After the development of microorganisms in the specified installation, it is planned to populate them in the collector of the house. Active reproduction and release of gas occurs on the 21st day. After this time, biological oxygen consumption will be measured. Its indicators are supposed to be used to assess the intensity of growth and reproduction of bacteria and, accordingly, as a criterion for the effectiveness of wastewater treatment and decomposition of organic material.

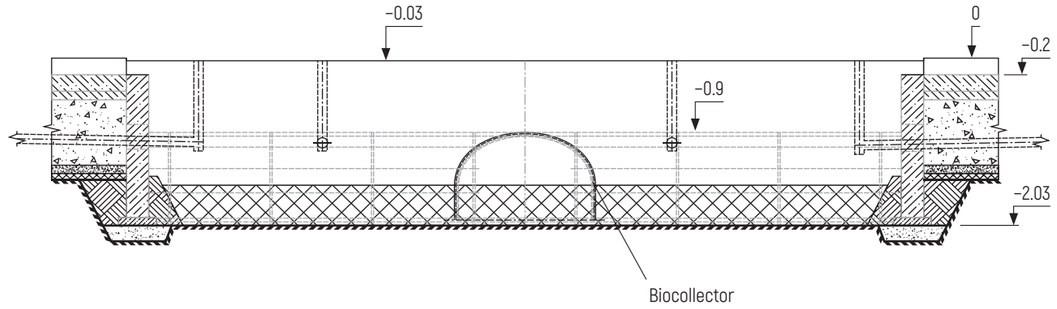


Figure 2 – Diagram of a domestic biocollector [17]

The study of microbiological parameters of wastewater samples was started at the previous stages of the experiment. The first results showed a significant decrease in the total number of microorganisms in the water taken from the collector – by 1,000–2,000 times [17]. Such a significant decrease in the number of bacteria may indicate water cleaning, since the mineralization of organic matter due to its decomposition leads to the absence of a feed base for putrefactive and fermenting bacteria and, as a result, to a drop in their numbers.

During the present research, the authors also selected two samples of the collector contents in the volume of 3 l to study possible gas formation and confirm the process of methanogenesis during the vital activity of microorganisms (Figure 3).

Figure 3 – Samples of wastewater from the collector

Purification of Gases from Methane with Biological Filters

During the vital activity of methanogenic bacteria, biogas is released, which is undesirable in an enclosed biological system. The resulting methane becomes explosive when mixed with air. Therefore, it is important to provide options for less risky use of methane. One of the disposal methods is the use of archaebacteria to produce biogas – an environmentally friendly, economical means alternative to fossil fuels. There is no need for additional generation of fuel from biogas under the conditions of an enclosed ECH ecosystem, since another energy source (solar) is being considered. In this regard, this article examines other options for the disposal of the resulting gas.

If we focus on the environmentally friendly and safe disposal of methane, one of the solutions to the neutralization of biogas can be the creation of capture systems [18]. The most promising way to capture methane and other biogas is biological filtration [19], which involves the removal and destruction of organic compounds contained in polluted air (for example, volatile organic substances or odorous substances), and the involvement of microorganisms. The air stream having organic pollutants is passed through a layer of biologically active substance (the basis of a biofilter), where pollutants are adsorbed in a biofilm, and then decomposed by special bacteria that use pollutants as a source of carbon and energy. An important fact: when pollutants and odorous substances decompose, usually harmless products such as carbon dioxide and water are formed. Since pollutants decompose and are not simply adsorbed, the biofilter does not retain the remnants of organic compounds removed from the polluted air stream (Figure 4).

As the basis of the biofilter, mixtures obtained from organic material are most often used: soil, compost, peat, sawdust. Sometimes synthetic materials are used.

Biofiltration is commonly referred to as a fixed film process. In most cases, the biofilm is formed by communities of various microorganisms (bacteria, fungi, yeast, etc.), macroorganisms (protozoa, worms, insect larvae, etc.), and extracellular polymeric substances.

The purified water can be periodically or continuously applied to the filter by lifting or lowering. As a rule, a biofilter presumes two or three phases:

- solid (medium);
- liquid (water);
- gaseous (air).

Organic matter and other components from the liquid diffuse into a biofilter in which processing takes place (mainly by biodegradation). The activity of microorganisms is a key factor in the efficiency of the process. A certain influence is also exerted by: the composition of water, the hydraulic load of the biofilter, the type of medium, the feeding strategy (seepage or immersion of the medium), the age of the biofilm, temperature, aeration.

The use of biofilters is justified when there are problems of emissions into the atmosphere associated with odor control, or contamination with volatile organic compounds has been detected. Gas purification is one of the main tasks when using composting equipment, biogas plants, sewage treatment plants, etc.

The efficiency of biofiltration depends on the ability of microorganisms to biodegrade pollutants. The cleaning capacity of biofilters is 75–99 %. The nature of the contamination is determined by a set of microorganisms immobilized in the biofilter.

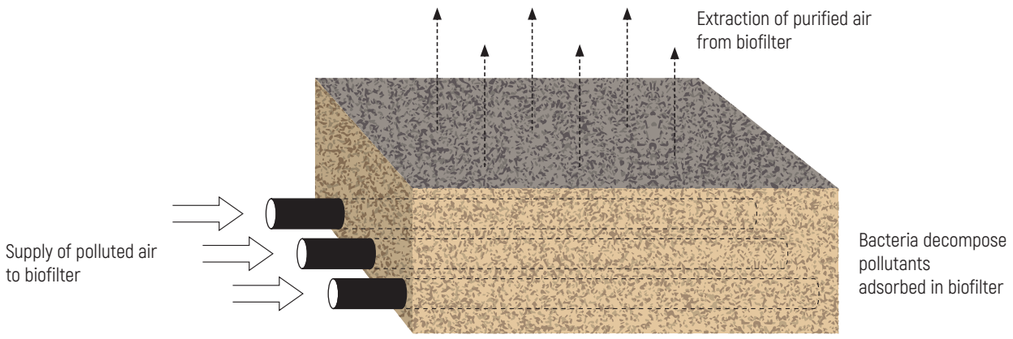


Figure 4 – Principle of biofiltration process [19]

When designing biofilters, it is extremely important to create optimal conditions for the efficient operation of microorganisms. They are set based on the metabolism features of the bacteria selected for biofiltration. Humidity, acidity, nutrients, and temperature are considered to be significant evaluation parameters.

The main advantages of biofilters are the low cost of the installation itself and low operating costs compared to a biogas plant.

Methanotrophic microorganisms are considered to be the most appropriate microorganisms capable of absorbing methane in biofilters. They are a group of methylotrophs (organisms that use single-carbon compounds for growth) that consume methane as the only source of carbon and energy. Such organisms are strictly aerobic gram-negative bacteria; they grow on simple mineral salts and methane. They include five genera: *Methylococcus*, *Methylobacter*, *Methylomonas*, *Methylocystis*, and *Methylosinus* [20]. At the first stage of their metabolic pathway, these aerobic organisms use the enzymes methane monooxygenase (MMO) to oxidize methane to methanol [21]. The rate of methane uptake by soil with lichens containing *Methyloaffinis lahnbergensis* ranges from –0.4 mg to –0.6 mg CH_4 $m^{-2}day^{-1}$ [22].

In addition to methanotrophic bacteria, some lower soil fungi can also absorb methane in the course of their vital activity. Methane for *Fusarium solani* fungus is a source of carbon and energy. The maximum eliminating capacity of *Fusarium solani* is 42.2 g CH_4 $m^{-3}h^{-1}$. There are biofilters based on the fungus *Fusarium solani*, as well as combined biofilters *Fusarium solani* with methanotrophic bacteria *Methylomicrobium album* and *Methylocystis sp.* Combined biofilters show a higher rate of methane uptake [23].

It is planned to conduct an experiment to study the consumption of methane by *Methylomicrobium*, *Methylocystis sp.* methanotrophs together with the fungus *Fusarium solani* [24]. The resulting biomass is used as an inoculum. The diagram of the laboratory unit is shown in Figure 5.

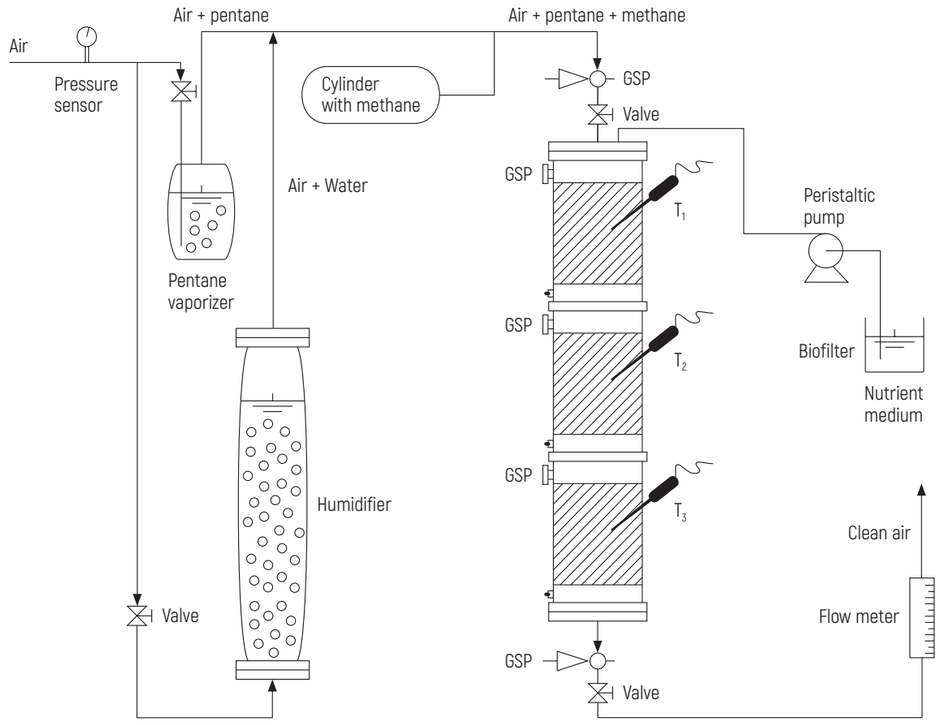
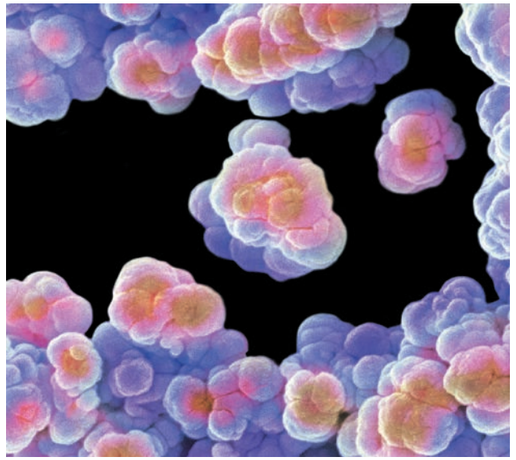


Figure 5 – Diagram of a laboratory installation for the study of methane removal by methanotrophs and *Fusarium solani* fungus [24]: GSP – gas sampling hole; T – thermoelement (T_1, T_2, T_3)



The proposed method of purification together with the cultivation of archaebacteria will be initially practiced in the collector of house No. 12 in the Unitsky's Farm Enterprise, and later (with successful tests) – in ECH.

Conclusions and Future Work

The possibility of using methanogenic archaebacteria in the processing of organic matter under the ECH conditions without oxygen consumption and the need for energy and materials to carry out the mineralization process is considered.

However, the vital activity of methanogens is associated with the release of methane, which makes it difficult to use them in an enclosed system. The solution to this problem can be the installation of biofilters, which allow to eliminate up to 99 % of lateral discharge from gaseous products formed during the anaerobic process of organic matter rotting. In addition, methane can be considered as a feedstock for the synthesis of methyl alcohol.

No viable archaebacteria were found in the collector of house No. 12 in the Unitsky's Farm Enterprise, so it is necessary to introduce this group of methanogenic microorganisms from outside. It is proposed to test a laboratory installation in terms of the production of biomass of archaea culture. Also, a method for cleaning the released methane using a biofilter is presented.

In the future, it is planned to select strains of aerobic microorganisms and methanotrophs capable of eliminating methane and other biological gases under the conditions of nature; to apply an installation for the cultivation of archaebacteria; to obtain the necessary number of bacteria; to conduct a prolonged experiment under the conditions of the collector of house No. 12 in order to study the survival ability of the culture being researched.

Archaebacteria strains are non-toxic to humans and their use is environmentally friendly within an enclosed ecosystem, which is a priority factor for ECH. Relict archaebacteria will contribute to maintaining the ecological balance, as well as increase the safety of organic waste bio-processing technologies.

To eliminate biogas from the system (in particular, its greater part – methane), it is proposed to additionally use biofilters that allow the decomposition of methane to carbon dioxide and water. This approach will help to avoid the negative effect of anaerobic decomposition of organic waste.

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UDC 579.64

Selection of Microorganisms Capable of Biodegrading Brown Coal with a View to Their Further Use in EcoCosmoHouse

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We have carried out a selection of microorganisms capable of biodegrading brown coal leading to an increase in the content of biologically active substances in it that have a positive effect on the growth and development of plants, i.e., humic acids. Possible stages of brown coal biodegradation were considered; a description was prepared regarding studies of brown coal biomodification using microorganisms possessing required enzyme systems for its use in their vital activities. These microorganisms can be used to prepare highly effective plant nutrition – brown coal-based natural humus that is considered for use in EcoCosmoHouse (ECH). We studied experimentally the ability of bacteria *Acinetobacter pittii*, *Enterobacter cloacae*, *Microbacterium sp.*, *Bacillus sp.* and microfungus *Trametes versicolor* to degrade brown coal. The intensity of brown coal biodegradation was determined depending on its concentration in the nutrient medium, the type of microorganisms, and the timing of the experiment. The experiments resulted in practical data that evidenced high destructive activity of microfungus *Trametes versicolor* and bacterium *Bacillus sp.* in regards to brown coal.

Keywords:
desert reclamation, brown coal, humic acids, biodegradation, biodestruction, soil microorganisms, bacteria, microfungi, humus, soil, EcoCosmoHouse (ECH), enclosed ecosystem.

Introduction

Brown coal was formed about 50 mln years ago from peat in the process of metamorphism (coalification) and is an intermediate link between peat and coal. The name of brown coal is due to the fact that it leaves a brown streak on the porcelain plate (unlike coal, which draws a black streak).

The brown coal composition may be presented in the following way:

- humin – humic substances that are insoluble neither in alkalis nor in an alkaline solution of sodium pyrophosphate. The main part of humin is plant residues of high molecular weight;
- bound (insoluble) humic acids – humic substances that are insoluble in alkalis, but soluble in an alkaline solution of sodium pyrophosphate;
- free (soluble) humic and fulvic acids – humic substances that are soluble in alkalis. These are more biologically active than insoluble humic substances;
- wide range of saturated and unsaturated hydrocarbons;
- soluble minerals, trace elements in a biologically available form;
- insoluble minerals, trace elements in a biologically inaccessible form.

The total content of humic acids in brown coal averages to about 20–50 %, but in some cases, it reaches 86 %. The ash content is usually within the range of 5–15 %, there is also brown coal with an ash content of up to 70 % [1]. The organic matter of brown coal has an irregular structure and includes, among other things, aromatic and polymer fragments that necessitate a careful selection of microorganisms and a thoughtful organization of conditions for their cultivation for biodegrading brown coal.

The microbiological composition of brown coal is diverse and is represented by various types of microorganisms (for instance, bacterial species *Bacillus*, *Rhodococcus*, *Arthrobacter*, *Micrococcus*, *Spirillum*, and *Cytophaga*, fungal species *Penicillium* and *Trichoderma*) [2, 3].

A wide variety of microorganisms was also found in drainage waters of an open pit coalmine where brown coal was mined: fungi of *Sporidiobolaceae* species, protozoan groups *Alveolata*, *Amoebozoa*, green algae of *Chlamydomonas* species, bacteria of *Acidiphilium*, *Sulfuriferula*, and *Thiomonas* species. The presence of such a diverse microbiome in waters saturated with brown coal supposes at least its non-toxicity with respect to these microorganisms and a theoretical possibility of their use in its biomodification [4].

Currently, most of brown coal is used as a fuel feedstock in coal-fired power plants of various types, as well as a feedstock for the chemical industry and agriculture. Smoke emissions from coal-fired power plants, as well as ash and slag waste, pose an environmental threat to many regions due to improper handling of these products of brown coal combustion that could be engaged, in case of their proper use, in various industrial sectors, including construction, agriculture, etc. [5, 6].

For energy purposes, brown coal must be burned without harm to the environment, with all waste processed in a single technological cycle. As a result, the maximum economic efficiency of such a process can be achieved without negative impact on the environment.

Biotechnological methods are an alternative option for processing brown coal that have a number of advantages over physical and chemical methods (including combustion):

- substandard, oxidized brown coal can also be used as raw material that have little value as fuel due to their low calorific value and significant content of fines [7, 8]. It is biodegradation with a low degree of metamorphism that can be more profitable from an economic point of view, since brown coal is less valuable energy raw material [9];
- they do not create waste and are safer ecologically;
- they can be used with moderate temperatures and pressure which reduces equipment requirement.

As a result of biotechnological brown coal processing, humus (organic fertilizer), biogas, desulfurized brown coal, sorbents of heavy metals can be obtained [10]. Humus production from brown coal is seen as the most promising direction, since it results in creating a valuable plant nutrition that falls under the organic category [11].

Humus produced from brown coal through processing by microorganisms (especially in combination with various types of secondary raw materials – manure, poultry droppings, food waste) can be effectively used in desert reclamation [12].

Frequent application of mineral fertilizers in large amounts contributes to accelerated humus decomposition that produces a significant increase in yield at the initial stage – up to two times. However, over time, a limit to an increase in fertility comes, and the use of mineral fertilizers results in a significant decrease in production of plant products due to the soil biocenosis destruction [13, 14].

An active and irregular use of agrochemistry leads to accumulation of pesticides, nitrates, and other harmful and toxic substances in the soil, and simultaneously in agricultural crops, that get subsequently into the human body [15].

The highly efficient humus produced from brown coal with a biotechnology will help to significantly reduce the environmental load on nature and make agriculture much less dependent on agrochemicals.

The purpose of this study is to research the ability of theoretically selected microorganisms to biodegrade brown coal; to determine optimal conditions required for that process.

Brown Coal Biodegradation Mechanism

Brown coal biodegradation can be conventionally divided into two stages:

- brown coal solubilization and its transfer to a more bioavailable state. It is limiting, since it is during the initial solubilization that complex degradable compounds convert to a soluble state. This is mainly due to the destruction of organic polymers and polynuclear aromatic hydrocarbons by the enzymatic mechanism. Besides, alkaline and chelator mechanisms work during brown coal solubilization that convert lower molecular weight compounds into a soluble form;
- transfer and incorporation of dissolved compounds into cell metabolism. The products of the first stage that are more bioavailable fragments with a lower molecular weight are involved into the metabolism of microorganisms and are converted into final products.

Lignin peroxidase, Mn-peroxidase, and laccase are known to be the principal enzymes involved in coal biodegradation [16].

In a case of microfungi, mycelium cells secrete necessary enzyme systems that act upon the substrate (in this case, brown coal), causing its destruction. Then, there occurs a complete or partial absorption of destruction products by the microfungal cells.

Bacteria produce enzymes required for brown coal decomposition into the external environment and then, similar to fungi, absorb the formed exometabolites; however, intracellular mechanisms of destruction can also be used.

Thus, for brown coal biodegradation, the use of microorganisms possessing one or more of the above enzymes will be the most promising.

For instance, researchers from the National Scientific Center (Poland) studied brown coal biosolubilization using an adapted microfungus *Fusarium oxysporum* LOCK 1134. They used a liquid nutrient medium with an addition of 5 % brown coal. The experiment was carried out for 14 days while stirring the mixture at a speed of 180 rpm.

At the end of biomodification, the concentration of biosolubilized brown coal in this solution was 1,474 mg/l. At the same time, no solubilization was observed in the control experiment [17].

A group of scientists from the Academy of Finland analyzed specific features of *Phlebia radiata* fungus enzymes production during biodegradation of artificially produced brown coal. In those studies, the maximum activity of fungal enzymes was noted at the minimum concentration of manganese in the nutrient medium (without its addition), and the degree of substrate mineralization was 30 % in 18 days. The cultivation was carried out at 28 °C on a solid nutrient medium with a lack of nitrogen [18].

The Institute of Chemistry and Chemical Technology of the Siberian Branch of the Russian Academy of Sciences carried out brown coal biodegradation under aerobic conditions using bacteria *Acinetobacter calcoaceticus* VKPM B-4833 adapted to brown coal, which resulted in the content of free humic acids increase by 22.9–30.6 % as compared to the initial substrate. They revealed signs of surfactants that do not belong to humic acids present in the biomodified substrate. The cultivation process took 10–60 hours; it was carried out at a temperature of 29–30 °C, under aeration and mixing; the brown coal concentration in the liquid substrate was 20 % [7].

In another experiment, scientists from the A.N. Bach Institute of Biochemistry Russian Academy of Sciences studied transformation of humic substances by basidiomycetes and *Trametes hirsuta*, *Trametes maxima*. The fungi were grown for 30 days at 28 °C and 80–90 % humidity on a solid mineral nutrient medium; the concentration of highly oxidized brown coal was about 2.7 % by weight. In the course of this experiment, loosening was noted on the brown coal particle surfaces that is a direct evidence of its biodegradation [19].

Materials and Experimental Methods

For this study, we selected microfungus *Trametes versicolor* and bacteria *Acinetobacter pittii*, *Enterobacter cloacae*, *Microbacterium sp.*, *Bacillus sp.* that possess the required enzyme systems and/or agronomically valuable features, such as nitrogen fixation, phosphate solubilization, etc.

Two experiments were carried out. One experiment was to determine brown coal destruction activity by bacteria species *Acinetobacter pittii*, *Enterobacter cloacae*, *Microbacterium sp.*, *Bacillus sp.*, the second one analyzed the brown coal destruction ability of microfungus *Trametes versicolor* individually and together with bacteria *Bacillus sp.*

Experiment No. 1

To determine destructive activity of bacteria *Acinetobacter pittii*, *Enterobacter cloacae*, *Microbacterium sp.*, *Bacillus sp.* in relation to brown coal, we used a mineral medium with varied brown coal concentrations added (Figure 1). The positive control (assuming the maximum microorganism growth) was a mineral medium with an addition of 10 % beer wort. After inoculation, the flasks were closed with cotton gauze plugs and installed on an orbital shaker, where, under constant stirring at a speed of 120 rpm, the selected microorganisms were cultivated on nutrient media with varied brown coal concentrations. The total viable count (TVC) was determined at the beginning, in the middle, and at the end of the experiment; based on this indicator, a conclusion was drawn on the destructive activity of microorganisms in relation to brown coal.

The composition of experimental nutrient media was as follows:

- Medium No. 1 (KH_2PO_4 – 0.9 g/l; K_2HPO_4 – 1.74 g/l; $MgSO_4 \times 7H_2O$ – 0.3 g/l; NaCl – 0.5 g/l; $CaCl_2$ – 0.1 g/l) – control;
- Medium No. 1 + 0.5 % brown coal;
- Medium No. 1 + 1 % brown coal;
- Medium No. 1 + 2 % brown coal;
- Medium No. 1 + 2.5 % brown coal;
- Medium No. 1 + 5 % brown coal;
- Medium No. 1 + 10 % beer wort – positive control.

The volume of experimental media was 1 l.

The TVC was monitored during the experiment. It was measured at the initial, intermediate, and final points of the study (see the Table).

Figure 1 – Experimental flasks with brown coal

Table – Brown coal destructor TVC dependent on the time and concentration of brown coal

Microorganism and medium	TVC Jan/04/2021	TVC Jan/11/2021	TVC Feb/18/2021
Acinetobacter pittii			
Medium No. 1	2.5×10^8	1×10^7	1×10^6
Medium No. 1 + 0.5 % brown coal	2.5×10^8	1×10^7	1×10^9
Medium No. 1 + 1 % brown coal	2.5×10^8	1×10^7	1×10^9
Medium No. 1 + 2 % brown coal	2.5×10^8	1×10^7	1×10^9
Medium No. 1 + 2.5 % brown coal	2.5×10^8	1×10^8	1×10^{10}
Medium No. 1 + 5 % brown coal	2.5×10^8	1×10^8	1×10^{10}
Medium No. 1 + 10 % beer wort	2.5×10^8	1×10^8	1.5×10^{12}
Enterobacter cloacae			
Medium No. 1	1×10^{10}	1×10^9	5×10^9
Medium No. 1 + 0.5 % brown coal	1×10^{10}	1×10^9	5×10^{10}
Medium No. 1 + 1 % brown coal	1×10^{10}	2×10^9	1.5×10^{12}
Medium No. 1 + 2 % brown coal	1×10^{10}	1×10^9	1×10^{10}
Medium No. 1 + 2.5 % brown coal	1×10^{10}	1×10^9	1×10^9
Medium No. 1 + 5 % brown coal	1×10^{10}	5×10^9	5×10^9
Medium No. 1 + 10 % beer wort	1×10^{10}	2×10^9	2×10^9
Microbacterium sp.			
Medium No. 1	1×10^9	1×10^8	5×10^7
Medium No. 1 + 0.5 % brown coal	1×10^9	1×10^9	1×10^{10}
Medium No. 1 + 1 % brown coal	1×10^9	1×10^9	2.5×10^{11}
Medium No. 1 + 2 % brown coal	1×10^9	3×10^9	1×10^{12}
Medium No. 1 + 2.5 % brown coal	1×10^9	1×10^{10}	1×10^{10}
Medium No. 1 + 5 % brown coal	1×10^9	5×10^9	7.5×10^{11}
Medium No. 1 + 10 % beer wort	1×10^9	3×10^9	1.5×10^{11}
Bacillus sp.			
Medium No. 1	1×10^8	2×10^8	1×10^{10}
Medium No. 1 + 0.5 % brown coal	1×10^8	1×10^9	5×10^{10}
Medium No. 1 + 1 % brown coal	1×10^8	1×10^9	8×10^{11}
Medium No. 1 + 2 % brown coal	1×10^8	1×10^9	1×10^{12}
Medium No. 1 + 2.5 % brown coal	1×10^8	1×10^9	3×10^{12}
Medium No. 1 + 5 % brown coal	1×10^8	1×10^{10}	5×10^{12}
Medium No. 1 + 10 % beer wort	1×10^8	2×10^9	2×10^{11}

It can be seen from the data presented in the Table that in most cases, the number of microorganisms in the cultures of *Acinetobacter pittii*, *Enterobacter cloacae*, *Microbacterium sp.*, *Bacillus sp.* increased by 1–3 orders after incubation in the media with brown coal as compared to the original quantities introduced into the dummy mineral medium. This may suppose that microorganisms use organic compounds of brown coal as a source of carbon and other nutrients and, consequently, they destruct brown coal. The greatest increase in biomass was shown by the culture of *Bacillus sp.*, the smallest – by *Acinetobacter pittii*.

The measured number of microorganisms is 10–500 times different on the average when comparing the brown coal sample with the highest concentration in the nutrient medium (5 %) with the sample with the lowest concentration (0.5 %).

The *Acinetobacter pittii* and *Enterobacter cloacae* TVC first decreased in the intermediate checkpoint, but increased by the end of the experiment, which is due to conditions not typical for cultivation of these microorganisms that required a certain time to adapt. A similar picture might be probably seen with bacteria *Microbacterium sp.* and *Bacillus sp.*, however, their adaptation might occur much faster.

During *Enterobacter cloacae* cultivation, the maximum TVC was fixed for the brown coal concentration of about 1 %. It is obviously caused by the presence of substances in brown coal that slow down the development of these microorganisms under certain conditions. At a concentration of 5 %, the *Enterobacter cloacae* TVC is slightly higher than at 2.5 %, which is a sign of a faster microorganism adaptation due to more intense exposure to various compounds contained in brown coal. A similar result is observed during cultivation of bacterium *Microbacterium sp.*, but the maximum concentration here occurs at the 2 % brown coal concentration.

The *Enterobacter cloacae* and *Bacillus sp.* TVCs on the nutrient medium that contains 5 % brown coal are 5×10^{12} and 5×10^{9}, which is higher as compared to growing with the use of beer wort – 2×10^{11} and 2×10^{9}, respectively. This may indicate their effectiveness in brown coal biodegradation even in the presence of sugars in the nutrient medium, or that the maximum growth was passed and the stage of dying off began.

On the whole, the data obtained indicate a fairly productive growth of the tested microorganisms on a medium with brown coal and, consequently, the coal destruction by microorganisms when it is used as a nutrient source.

Experiment No. 2

The experiment was conducted to determine in practice the destructive activity of microfungus *Trametes versicolor* against brown coal. Besides, we studied brown coal destruction by fungus *Trametes versicolor* and bacteria *Bacillus sp.* when they were co-cultivated in the same nutrient medium, as *Bacillus sp.* demonstrated the best growth in Experiment No. 1 and, being nitrogen fixers, they may produce an additional nitrogen source for the microfungus growth and development.

The experiment used a mineral medium with an addition of brown coal in varied concentrations, as well as a Sabouraud medium as a positive control. After inoculation, the flasks were closed with cotton gauze plugs and installed on an orbital shaker, where the selected microorganisms were cultivated on nutrient media with various concentrations of brown coal under a continuous stirring at a speed of 120 rpm. The study duration was six weeks.

The composition of experimental nutrient media was as follows:

- Medium No. 1 (KH_2PO_4 – 0.9 g/l; K_2HPO_4 – 1.74 g/l; $MgSO_4 \times 7H_2O$ – 0.3 g/l; NaCl – 0.5 g/l; $CaCl_2$ – 0.1 g/l) – control;
- Medium No. 1 + 5 % brown coal;
- Medium No. 1 + 10 % brown coal;
- Medium No. 1 + 20 % brown coal;
- Medium No. 1 + 50 % brown coal;
- Sabouraud medium – positive control.

During the experiment, the following measurements were made:

- amount of humic acids in brown coal of the nutrient medium before and after cultivation (Figure 2) [20];
- TVC before and after cultivation. It was established by the method of determining the quantity of mesophilic aerobic and facultative anaerobic microorganisms (QMAFAnM) on a solid nutrient medium [21].

The TVC measurement results were as follows: in all samples, the quantity of bacteria was 1×10^{7} at the beginning of the experiment and varied within $1.1–1.2 \times 10^{7}$ at its end, which evidences a possible suppression of *Bacillus sp.* growth by microfungus *Trametes versicolor*, as bacteria *Bacillus sp.* grew much faster under similar cultivation conditions (Experiment No. 1).

Conclusions and Future Work

Brown coal biodegradation is a topical scientific challenge. This process allows producing various types of industrial products (humus or organic fertilizers, biogas, sweet brown coal, sorbents). Brown coal biodegradation technologies are ecologically safe; however, they require careful selection of microorganisms and cultivation conditions.

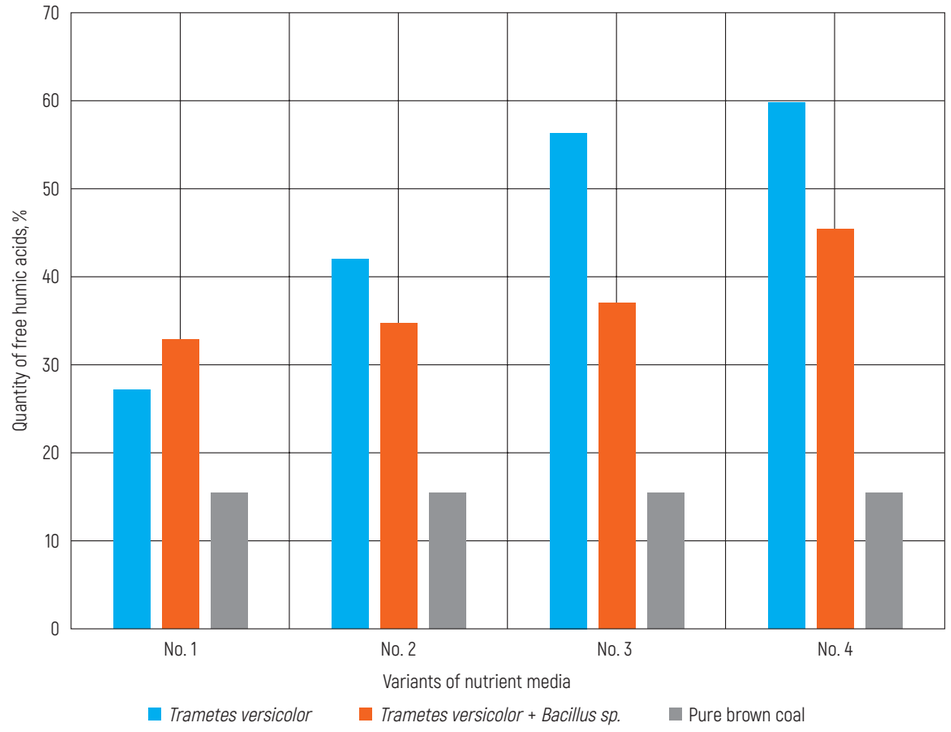

Figure 2 – Amount of humic acids in the samples and the initial brown coal
(brown coal content in nutrient media: No. 1 – 50 g/l; No. 2 – 100 g/l; No. 3 – 200 g/l; No. 4 – 500 g/l)

A limiting stage of brown coal biodegradation is its solubilization by means of a mechanism of enzymatic cleavage of hard-to-degrade organic compounds (polynuclear aromatic hydrocarbons, polymer structures) contained in its composition.

The following microorganisms with suitable enzyme systems have been tested for biodegradability of brown coal: microfungus *Trametes versicolor*, bacteria *Acinetobacter pittii*, *Enterobacter cloacae*, *Microbacterium sp.*, *Bacillus sp.*

Among the bacteria tested, the most active growth on a brown coal containing medium was demonstrated by *Bacillus sp.* the TVC whereof increased from 1×10^{8} to 5×10^{12} in two weeks of cultivation on a mineral medium with added 5 % brown coal, which makes it prospective as a brown coal destructor bacterium.

During the process of growing *Trametes versicolor* microfungus on a mineral medium containing brown coal in the amount of 50 % (500 g/l), the concentration of free humic acids in brown coal increased more than three times (analyses for the content of free humic acids in brown coal samples after biodegradation were carried out several times to exclude a technical error). The data obtained that demonstrated a multiple increase in free humic acids make the microfungus *Trametes versicolor* promising as a brown coal destructor microorganism and, therefore, require additional research.

Considering an extremely insignificant growth of bacteria *Bacillus sp.* when cultivated with the microfungus *Trametes versicolor*, it can be concluded that *Trametes versicolor* inhibits a growth of *Bacillus sp.*, meaning that their joint cultivation is inappropriate.

In the future, we are planning to carry out a more in-depth theoretical and practical study of brown coal biodegradation using the microfungus *Trametes versicolor* and other microorganisms (including algae and protozoans) and to analyze the effects of the humus produced on the plant growth and development.

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UDC 621:622

Reduction of Environmental Impact Using Brown Coal Due to Its Advanced Refining

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Some aspects of the brown coal separation into derivatives using the electrohydropercussion material dispersion technology are considered. The derived coal-water slurry is used as a base material (raw material) to manufacture the products in demand in the power industry and agriculture – water-coal fuel, liquid fertilizers based on humic acids. Separation of brown coal into its components (water-soluble organic part and dispersed inorganic part), carried out at the first stage of its refining, ultimately allows to achieve a reduction in anthropogenic environment load.

Keywords:
brown coal, electrohydropercussion unit, dispersion and extraction of coal, water-coal fuel, humic substances.

Introduction

The EcoSpace program substantiates the need to solve global anthropogenic problems due to human activity [1]. This requires to launch manufacturing of ecologically pure food products (uGreen); eco-oriented construction of buildings and structures for living and work (EcoHouse); generation of clean energy and heat (uEnergy); operation of eco-oriented transport (uST); bringing hazardous industry into near space (uSpace) [2].

The authors of the article propose a development that will allow to use the output products in the development of uGreen and uEnergy. The scientific essence of the research is the advanced separation of brown coal into derivatives using electrohydropercussion material dispersion technology.

Electrohydropercussion Technologies in Brown Coal Dispersion

Brown coal is a solid combustible sedimentary rock of vegetable (partially animal) origin, formed in the process of biochemical, physico-chemical, and physical changes. It is an intermedium between peat and hardcoal [3]. Brown coal, as a result of plant or biomass metamorphism, has a complex structure [4]. Conventionally, it contains organic and inorganic components.

The organic part of coal varies by a particular deposit, but always includes humates [5]. Humic preparations produced on their basis are widely used in agriculture as plant growth stimulants, antioxidants, and heavy metal sorbents that has a positive effect on the environment [6–9]. The inorganic part of coal (except for carbon) also includes a whole set of chemical elements and their oxides [10].

In recent decades, despite considerable achievements in the development of alternative (green) energy generation methods, such a traditional method of heat and energy extraction like burning of gas, fuel oil, and coal remains unaltered. The data on quantity of energy are shown in Figure 1 (adapted from [11]).

The charts characterizing prospective demand (Figure 1) are plotted based on two scenarios that were proposed by the International Energy Agency (IEA) and announced in the annual global energy forecast for 2020. The Stated Policy Scenario (STEPS) is indicated with solid lines. The Sustainable Development Scenario (SDS) is indicated with dotted lines. Other renewable energy sources include solar, wind, geothermal, and marine energy [11].

Despite the fact that the explored coal reserves (brown coal is 50 %) are several times higher than the total discovered reserves of oil and gas (by three times in energy equivalent), the share of coal ranks the more lower than the use of oil and gas in the world energy production, as is clear from the data shown in Figure 1 [12].

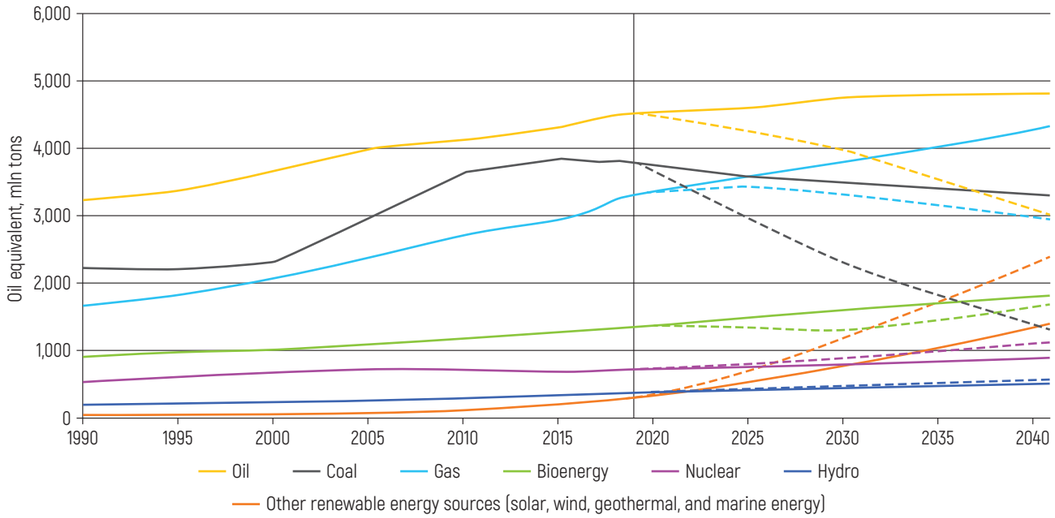

Figure 1 – Global natural energy demand in fuel equivalent (1990–2040)

When mining and burning brown coal, several factors arise that deteriorate the local and global environmental situation:

- rock dumps in the form of landfills due to the high overburden ratio (indicator of the ratio of the waste rocks volume to the amount of minerals [13]);
- carbonic dioxide (CO_2) emissions;
- acid rains formed due to emissions of sulfur dioxide (SO_2) and nitrogen oxides (NO, NO_2, N_2O_3);
- particulate matter emissions (furnace black) resulting from fractional combustion of coal;
- formation of ash disposal areas due to the high ash content of brown coal (their subsequent use is often problematic due to the lack of environmentally acceptable treatment technologies, as well as toxicity and radioactivity).

Since brown coal is the most inexpensive fuel [14], there is an economic reserve not only to increase the efficiency of its use (development of new technologies) but also to solve environmental matters and achieve an environmental impact level that does not exceed such values as, for instance, when burning gas.

Improving efficiency and overcoming environmental problems is achieved due to a certain technological process implemented at the following stages:

- fuel preparation for combustion;
- fuel combustion;
- filtration and purification of combustion products.

In this regard, the technology that provides the result at two stages at once seems promising:

- fuel preparation;
- filtration, purification, and absorption of combustion products.

It is technically possible to implement the solution of such seemingly diverse problems using an electrohydropercussion unit that extracts humic substances from brown coal along with its dispersion.

Dispersed coal is the basis of water-coal fuel (WCF). The scientific and technical literature describes in detail

the environmental and economic benefits of coal combustion in comparison with lump coal combustion process.

Humates physically extracted from brown coal are the basis for manufacturing of environmentally friendly humic preparations. The economic and environmental effect of their use in agriculture is also shown in detail in research papers.

Advantages of WCF combustion:

- significant reduction in nitrogen and sulfur oxide emissions;
- carbon elimination – 99.5 % (for reference: in lump coal combustion – 70 % [4, 10]);
- reduction in ash quantity by almost a third;
- possibility of using fine coal in the power industry, which in most cases goes into dumps and significantly worsens the ecology at the mining sites due to its volatility.

Benefits of using humic preparations:

- increase in growth rate of green biomass and, thus, increase in the amount of bound carbon oxide;
- favorable effect of forests and other vegetation on temperature fluctuations and humidity of the Earth's atmosphere. The growth of flora biomass requires the energy obtained from the environment. This leads to a reduction of day/night temperature fluctuations and a decrease in soil evaporation that has a positive effect on agriculture and planetary ecology in whole;
- reduction in the amount of application of non-ecological mineral fertilizers designed to accelerate the growth of agricultural plants.

The topic of using electrohydropercussion units for substance extraction matter [5, 15–17] or coal dispersion [18–21] only is not new. However, as far as the authors of the article are aware, the process of combined dispersion and extraction has not been considered anywhere. Simultaneous conduct of these processing procedures provides a more significant ecological and economic effect.

Results

To solve the set tasks, a laboratory of UniThorr electrohydropercussion unit was designed and fabricated (Figure 2). Its functionality is based on the electrohydraulic effect [22].

The authors investigated the performance capabilities of the UniThorr unit for coal dispersion [18] in the production of environmentally friendly high-fertile UniTerra (uTerra) soils, as well as by WCF. The processes of extracting water-soluble humates from brown coal were studied. Applicability of the derived product (solid and liquid fractions of coal-water slurry) for the relevant areas was tested under laboratory conditions. Fractional screening was used to determine the grain size. The content of the organic component was analyzed by the method of permanganate oxidizability.

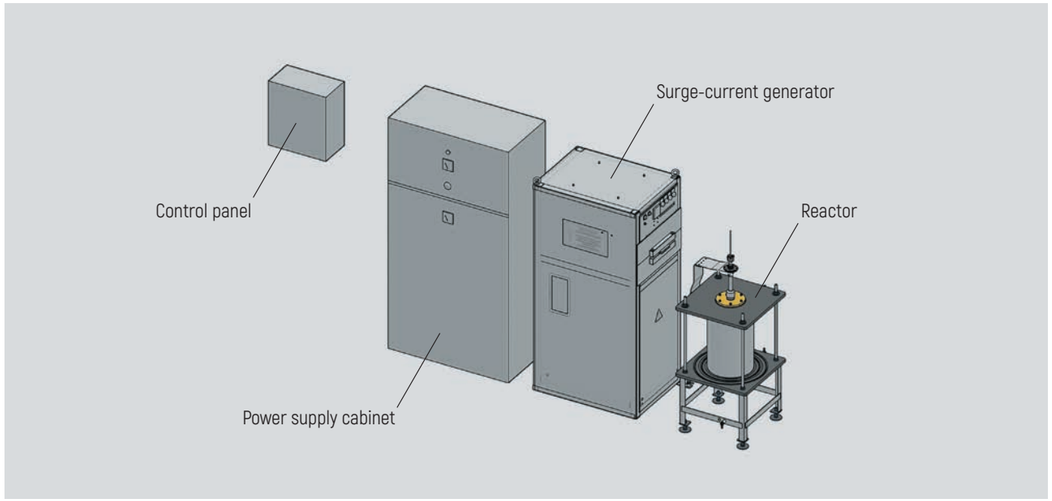

Figure 2 – Overall view of UniThorr electrohydropercussion unit

Figure 2 shows the main elements of the UniThorr unit. Its specifications are shown in the Table.

Table – Main specifications of UniThorr electrohydropercussion unit

Technical specification	Value
Supply voltage, V	220
Service voltage, kV	50
Pulse energy, J	150
Power consumption, W	600

At the presented unit, a significant number of coal-water mixture samples were processed in a discrete mode with various coal and water ratios and values of the inter-electrode gap. The purpose of the research is to obtain the optimal process parameters of the electrohydropercussion treatment of brown coal. The goal of this process is to achieve maximum performance and the highest quality for coal dispersion. The requirements to the final size of coal fractions were compiled both based on the requirements to the raw material the WCF is produced of [5, 15], and the conditions whereby the most rapid extraction of humates occurs.

The result of the experiments was the determination of a number of trends and patterns.

To achieve the best dispersion, the optimal parameters have been determined:

- mass coal and water ratio;
- electrode gap.

The influence of the following factors was described:

- volume of loaded coal on the rate of its dispersion;
- amount of fine particle fraction on the rate of dispersion;
- inorganic impurities on the rate of dispersion;
- foreign impurities on the unit performance (compared to wet mechanical grinding systems) [23].

During the treatment of coal-water slurry, samples (of the liquid component with the organic matter contained in it) were taken at different intervals, for which the dynamics of changes in the content of the organic component was studied by the method of determining permanganate oxidizability (GOST R 55684-2013 (ISO 8467:1993), method B).

It was revealed that permanganate oxidizability reduces with an increase in treatment time that can be explained by the effect of ozone (generated during operation of the unit) leading to oxidation and decomposition of organic matter. It should be noted that water ozonation is a reasonably well-known method of its purification from organic impurities [9].

Conclusions and Future Work

The potential reduction in the environmental load occurring while using brown coal in production as a result of its complex refining was analyzed. The method presented in the article involves the separation of coal into organic and inorganic components contained in the liquid and solid fractions of coal-water slurry. This processing procedure was approbated using the laboratory of UniThorr electrohydropercussion unit, designed and fabricated at the Unitsky String Technologies Inc. (Minsk, Republic of Belarus).

The continuation of the research and implementation of the solution proposed by the authors will contribute to the preservation of the Earth's biosphere and rational use of natural resources as a guarantee of environmental stability on the planet. This approach meets the objectives of the EcoSpace program ongoing to the extent of intensification of environmental protection and is applicable in the uSpace program developed by the Astroengineering Technologies LLC (Minsk, Republic of Belarus) in cooperation with Unitsky String Technologies Inc.

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UDC 663.51

Food Solar Bioenergy

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The article presents a study on the creation of an enclosed balanced food solar bioenergy (FSBE). This direction is one of the components of the uEnergy eco-oriented technological platform needed for the implementation of the EcoSpace program. The authors analyzed the methods of obtaining alcohols from virtually unlimited renewable plant resources; studied the specifics of the use of alcohols as fuel. They have substantiated the importance of using a complex resource-saving technology in the production of alcohols and proposed methods for manufacturing animal feed and human food from secondary products of alcohol production. The widespread consumption of this type of alternative fuel developed by the authors poses new tasks for the adaptation of power plants, arrangement of a new type of enterprises supporting integrated approaches to solving environmental and social problems. The technology in question can be implemented in linear cities to provide them with electricity and heating, as well as in an Equatorial Linear City (ELC) with a length of 40,000 km.

Keywords:
renewable energy sources, biofuel, ethanol, methanol, butanol, alternative power industry, renewable vegetable raw materials, sugar beet.

Introduction

The EcoSpace program is aimed at overcoming environmental problems associated with the development of technogenic civilization, as well as at establishing a new world structure. One of the important solutions proposed in the program is the removal of the polluting industry outside the Earth's biosphere. The basis of the future cosmotechnogenic terrestrial civilization, coping with global environmental, resource, and socio-political challenges on the planet, will be a new world – the EcoSpace. According to the program author, engineer A. Unitsky, this perfect world will be based on three main components designed to provide the entire needed set of conditions for a safe and sustainable development of the Earth's civilization in the foreseeable future:

- BioSpace – the Earth's biosphere, free from external anthropogenic impact, restored, and naturally evolving;
- TechnoSpace is a technosphere re-equipped on Earth with biospheric technologies and newly created in near space, which does not have an anthropogenic oppressive effect on the terrestrial biosphere and is much more energy and resource efficient;
- HomoSpace is an improved global socio-political system that covers societies living on the planet and in space [1].

According to the EcoSpace program, the key link of the Earth's eco-renewed technosphere is an Equatorial Linear City (ELC) – the terrestrial component of the geocosmic transport and communication complex, on the territory of which there is a takeoff and landing overpass of a General Planetary Vehicle (GPV) with all the infrastructure required for carrying out GPV flights and servicing global geocosmic cargo and passenger transportation to the Industrial Space Necklace "Orbit" (ISN "Orbit") and back to the Earth. The ELC consists of cluster-type settlements harmoniously integrated into the natural environment of the terrestrial and oceanic areas of the planet, interconnected with uNet routes and located on a strip along the equator [2].

The ELC provides the following:

1) production of natural and environmentally friendly food products – pre-industrial analogues (when agriculture did not know chemical fertilizers and pesticides);

2) obtaining green electricity and heating (otherwise cooling in warm countries) without harming the biosphere of the planet;

3) construction of eco-comfortable housing, industrial buildings and structures;

4) transport and energy information eco-oriented infrastructure.

These conditions will provide the following eco-oriented technological platforms:

- uGreen – pre-industrial organic farming;
- uEnergy – green power industry, mainly relict solar bioenergy;
- uST – Unitsky String Technologies;
- EcoHouse – eco-oriented residential and industrial construction [1].

The creation of an eco-oriented technology platform uEnergy involves the development and use of relict solar bioenergy and food solar bioenergy.

Relict solar bioenergy (RSBE) is a power industry based on the use of fossil brown coal and shale to produce clean energy and, along the way, living humus needed to restore the fertility of poor and desert lands. RSBE will activate the mineral wealth of ancient soils and the energy of the ancient Sun accumulated by plants during the Mesozoic and Cenozoic periods and stored in coal.

Food solar bioenergy (FSBE) is a power industry based on the complex consumption and processing of biomass of plants that have absorbed the energy of the Sun to produce biofuels, animal feed, and food for humans.

Biofuels are various types of combustible products derived from vegetable raw materials, the main advantages of which are the renewability and accumulation of solar energy. Consequently, the use of biofuels in transport, industry, and power industry will not change the existing natural energy balance of the planet.

Annually, 170–200 bln tons of plant biomass (in terms of dry mass) are created in the Earth's biosphere, which is energetically equivalent to 70–80 bln tons of petroleum [3].

Alcohols are an environmentally friendly fuel that is practically equivalent to natural gas and exceeds the parameters of fuel produced from oil, while 1 l of ethanol corresponds to approximately 0.67 l of gasoline.

The cultivation of certain types of plants (for example, sugar beet) as raw materials for the production of alcohol makes it possible to obtain not only environmentally friendly fuel but also animal feed, food for people. The yield of sugar beet can reach more than 100 t/ha, which contributes to the production of about 10 tons of alcohol.

Global consumption of liquid fuel in 2020 amounted to 4.715 bln tons. In order to produce 1 bln tons of alcohol (about the same amount of gasoline is produced in the world today), it is necessary to use 1 mln km^2 of cultivated land, which is 21 times less than the area of deserts on the planet, occupying 21 mln km^2 (excluding the polar deserts of Antarctica and the Arctic). This means that by restoring the fertility of deserts only, humanity will be able to cover its need for environmentally friendly hydrocarbon fuel for millennia to come and provide foodstuffs for billions of people and animals.

Alternative Energy Sources

The growth of production and population leads to an increase in energy consumption. The climatic changes taking place on the planet have caused the search and development of alternative ways of obtaining energy.

Today, there is a need for new energy sources that will provide a raw material base, improve the state of the environment, and raise the standard of living of the population. The problem how to deal with the waste remaining after processing traditional energy sources is also a difficult task for industrial states [4].

Finding alternative energy sources based on renewable raw materials is a solution to many existing problems. The biomass of plants is of great interest in this case, since representatives of flora have a number of advantages over fossil hydrocarbons. Creation of an enclosed cycle of energy use and waste disposal will help in the issue of providing energy, animal feed, food for humans, organic fertilizers for plants. An integrated approach in the process of obtaining and using alcohols as fuel (includes cultivation of the required raw materials, fuel production, processing of alcohol production waste) allows to cope with the challenges.

Photosynthesis underlies in the base of the vital activity of plants, which, absorbing carbon dioxide from the air and water from the soil, under the influence of solar radiation produce carbohydrates – compounds of carbon, oxygen, and hydrogen. As a result of complex biochemical transformations, a variety of organic compounds appear from carbohydrates. They make up the parts of plants – sugars, cellulose, starch. They can serve as raw materials for the production of alcohols.

The process of photosynthesis is simplified by the formula (1):

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6\ (\text{glucose}) + 6O_2. \quad (1)$$

A carbohydrate molecule and six oxygen molecules are created from six carbon dioxide molecules and six water molecules under the impact of solar radiation.

Plants build cells and tissues from several basic elements – carbon, oxygen, and hydrogen; the content of other chemical elements is insignificant.

In addition, plants have a zero-carbon balance. After their death (in the process of rotting and decomposition by microorganisms), CO_2 is released. Its amount corresponds to the volume of carbon dioxide absorbed by plants during their growth.

Alcohols are organic substances, derivatives of hydrocarbon (CH), which include a hydroxyl group (OH) and consist of the same elements – carbon, oxygen, and hydrogen. When producing alcohols from renewable raw materials and using them as fuel, a zero-carbon balance is also maintained.

Use of Alcohols as Fuel

The use of alcohols obtained from renewable vegetable raw materials as a motor fuel has many advantages.

An essential advantage is the improvement of the ecological situation. An internal combustion engine running on alcohols contributes to a significant reduction in emissions of the main toxic components (carbon monoxide, unburned hydrocarbons, nitrogen oxides). In addition, the efficiency of the engine increases by 5–10 % compared to an engine running on gasoline. The use of alcohols is characterized by a minimum duration of the carbon cycle.

The most commonly used fuels for internal combustion engines are methanol, ethanol, and butanol.

Methanol (methyl alcohol) has the formula CH_3OH. It is a transparent colorless liquid with a faint smell of ethanol, easily ignites and provides smokeless combustion. It is toxic to the human body (up to fatal if ingested). Methanol is characterized by increased corrosion activity in relation to some structural materials (for example, aluminum), which requires refinement of the standard fuel system of the vehicle.

Ethanol (ethyl alcohol) has the formula C_2H_5OH. It is a transparent colorless liquid with a characteristic odor, easily flammable, hygroscopic, dissolves well in water in any proportions (like methanol), has a narcotic effect on the human body. Unlike other alcohols, it has become the most widespread as a motor fuel.

Butanol (butyl alcohol) has the formula C_4H_9OH. It is a colorless, slightly oily liquid with a noticeable fusel smell. Several isomeric forms are known, 1-butanol $CH_3(CH_2)_3OH$ is used as fuel. It has a higher calorific value than other alcohols, close to that of gasoline. It mixes well with organic solvents, but does not dissolve very easily in water, creating a 7.6 % solution. Butanol has no narcotic effect on the human body; if it gets on the skin, it can cause irritation, and its vapors are dangerous for the mucous membranes.

Gasoline is a mixture of light hydrocarbons with a boiling point range of 30–205 °C. It is a colorless or barely yellowish liquid, easily ignites, actively evaporates at temperatures above 30 °C, the vapors of this oil product create an explosive mixture at a concentration of 0.8–8 vol. %. It has a narcotic effect on the human body; vapors cause irritation of the mucous membranes; negative consequences may occur if gasoline gets on the skin.

Table 1 compares the properties of alcohols and gasoline. From the data presented, it can be seen that alcohols are characterized by less energy per unit weight and unit volume than gasoline, but do not require more air for combustion. The calorific values of fuel-air mixtures differ slightly.

Alcohols have a greater heat of evaporation, methanol has this indicator by 3.3 times higher than for gasoline. The greater the heat of evaporation of the fuel mixture is, the more energy must be borrowed from the engine parts in contact with the fuel. This aspect leads to a decrease in the temperature of the combustible mixture before the power stroke. Accordingly, cooling of especially heat-loaded engine parts (valve and piston) is much more efficient. The temperature of the fuel mixture during the intake stroke is also lower, which contributes to an increase in the filling of the cylinders with the fuel mixture – there appears a compressor effect of alcohol mixtures. So, when using methanol, the maximum combustion temperature of the alcohol mixture is about 200 °C less than for gasoline.

The ratio of air and fuel for alcohols is lower than for gasoline, so it is possible to supply a more enriched mixture and thereby increase the engine power. An increased amount of alcohol entering the engine cylinders has an additional cooling effect [5].

Unlike gasoline, alcohols contain an oxygen atom, which contributes to the complete combustion of the fuel-air mixture, as well as to the reduction of carbon formation. When using alcohols as components of motor fuel, emissions of carbon monoxide (CO) and nitrogen oxides (NO_x) are reduced by 5–15 % and more.

Gasoline has a calorific value per volume unit greater than that of alcohols. This property increases the consumption of alcohol mixtures compared to gasoline: for ethanol – by 156 %, and for methanol – by 209 % of gasoline consumption. In order to compensate for the excessive consumption of alcohol mixtures, it is necessary to increase the volume of fuel tanks and change the fuel supply system.

An engine running on an alcohol mixture is much more difficult to start at low and especially negative temperatures than that operating on gasoline. This is due to the high flash point, worse (compared to gasoline) evaporation of alcohols, as well as the formation of condensate on the electrodes of spark plugs.

Table 1 – Properties of alcohols and gasoline

Product features	Methanol	Ethanol	Butanol	Gasoline
Density, kg/m^3	792	794	810	725–780
Octane number, units	150	105	96	95
Calorific value, MJ/kg	19.9	26.8	33.7	44
Air-fuel ratio, kg of air/kg of fuel	6.42	9	11.1	14.95
Heat of evaporation, MJ/kg	1.2	0.92	0.43	0.36
Calorific value of fuel-air mixture, MJ/kg of mixture	2.68	2.68	2.78	2.75
Flash point, °C	6	13	34	–43
Self-ignition temperature, °C	440	422.8	340	255–370
Freezing point, °C	–97.6	–114.15	–89.8	–70*
Degree of exposure hazard to the human body, class	3	4	3	4
Maximum permissible concentration (MPC) of vapors in the air of the operational area, mg/m^3	5	1,000	10	100

* Depending on the additives used.

Fuel Mixtures

Various alcohol mixtures are used as motor fuel. Flexible-fuel vehicle (FFV) can use several types of fuel mixtures: gasoline, alcohol, and their combinations. Fuel containing alcohol has an alphanumeric designation. The letters indicate the alcohol involved: E – ethanol, M – methanol, B – butanol; the numbers indicate the percentage of alcohol in the mixture by volume (Table 2).

Certain alcohol-gasoline fuel mixtures are common in different countries. The most popular are [6]:

- E5, E10 – mixtures with a low ethanol content (5 %, 10 %) and a minimum volume of water (less than 1 %) (anhydrous ethanol). They are actively used in more than 20 countries. They can provide reliable operation of internal combustion engines without modification of the fuel system or engine. They are approved for use in all new cars in the USA, and in some states are mandatory for use. The addition of a small amount of ethanol reduces harmful emissions, increases the octane number by 2–3 units, and allows to remove the harmful oxygenating additive of methyl-tret-butyl ether (MTBE). MTBE is in great demand among fuel manufacturers in order to increase the octane number and improve fuel combustion;
- E15 – a mixture consisting of 15 % ethanol and 85 % gasoline. In the USA, the issue of using this mixture instead of E10 in cars younger than 2000 release year is being considered;
- hE15 – the mixture includes 15 % hydrous ethanol and 85 % gasoline. It has been used in the Netherlands since 2008 at state gas stations. Bringing ethanol into compliance with the specifications for anhydrous ethanol (water content less than 1 %) requires significant additional costs. In hydrous ethanol, a volumetric water content of 3.5–4.9 % is allowed, which is an inhibitor of "dry" corrosion from the effects of ethanol. Water injection reduces overall CO_2 emissions and has a positive effect on the thermodynamic efficiency of the engine;
- E20, E25 – mixtures containing 20 % and 25 % ethanol, respectively. Their active consumption has been observed since the late 1970s in Brazil. Gasoline engines of all cars produced in Brazil are adapted to operate with these mixtures. The E20 fuel mixture is common in Thailand, its use in the UK and some US states is being discussed;
- E70, E75 – mixtures in which 70 % and 75 % ethanol are allowed, respectively. They are used in FFV cars as a replacement for E85 in winter. A decrease in temperature leads to a drop in vapor pressure – at an indicator below 45 kPa,

Table 2 – Composition of alcohol fuel mixtures

Fuel mixture	Gasoline, %	Anhydrous ethanol, %	Hydrous ethanol, %	Methanol, %	Butanol, %	Fuel additive, %
E5	95	5				
E10	90	10				
E15	85	15				
hE15	85		15			
E20	80	20				
E25	75	25				
E70	30	70				
E75	25	75				
E85	15	85				
ED95		95				5
E100			100			
M85	15			85		
M100				100		
E85B		85			15	

ignition of fuel becomes difficult. At temperatures below 11 °C, an increase in the gasoline content and, accordingly, a decrease in the amount of ethanol makes it easier to start the engine and reduces ethanol emissions. E70 is used in the USA, E75 – in Sweden;

- E85 – a mixture made from 85 % of ethanol and 15 % of gasoline. It has an octane number equal to 108; it is standard for refueling FFV. It has become most widespread in Brazil and the USA;
- ED95 – the mixture is made of 95 % of ethanol and 5 % of a fuel additive that improves ignition. It is used in diesel engines modified to a higher compression ratio. The additive guarantees the normal operation of diesel engines. This type of fuel mixture is used in Sweden, Great Britain, Spain, Italy, Belgium, and Norway;
- E100 – it is 100 % ethanol. This alcohol is hygroscopic and absorbs water well. Obtaining anhydrous ethanol requires additional costs. E100 refers to direct hydrous ethanol. The azeotropic mixture includes 96.5 % of ethanol and 3.5 % of water in its composition by volume; it contains the maximum concentration of ethanol, which can be obtained by simple fractional distillation [6]. It has been used since the late 1970s in Brazil as a motor fuel for vehicles with specially designed engines. Can be used in FFV. The ANP specification (Brazil) defines a maximum water concentration in ethanol of 4.9 vol. % (approximately 6.1 wt. %);
- M85 – a mixture containing 85 % of methanol and 15 % of gasoline. It was distributed in 1980–2005 in the state of California (USA). Suitable for refueling FFV. The use of the mixture is discussed in countries such as India, Brazil, China;
- M100 – 100 % methanol. An independent motor fuel; improves the performance of the engine, increases its power and torque. FFV are capable of running on pure methanol;
- E85B – a mixture comprising 85 % of ethanol and 15 % of butanol. The long hydrocarbon chain of butanol makes it look more like gasoline than ethanol. An engine designed to run on gasoline can be operated on butanol without any modification.

Technology for Producing Alcohols

Technologies for producing alcohols are divided into biochemical (production of bioalcohols from renewable vegetable raw materials) and chemical (production of synthetic alcohols from mineral raw materials).

Renewable vegetable raw materials, which can be used in the process of producing alcohols, include all its types containing carbohydrates. The method of producing ethanol from agricultural crops has been known since ancient times. This is an alcoholic fermentation of vegetable raw materials, including carbohydrates (starch, glucose, fructose, etc.), under the action of yeast and bacterial enzymes. The scheme of the fermentation process is expressed by the formula (2):

$$C_6H_{12}O_6 \text{ (glucose)} \rightarrow 2C_2H_5OH \text{ (ethanol)} + 2CO_2. \quad (2)$$

As a result of fermentation, a solution is obtained that contains ethyl alcohol in a concentration of up to 15 %. At a higher alcohol concentration, yeast usually dies. Ethyl alcohol produced in this way needs further purification and concentration, usually this is done by distillation.

For the preparation of ethyl alcohol, agricultural crops with a significant sugar or starch content are often used: sugar cane, corn, potatoes, cereals, sugar beet, etc.

Modern industrial technologies make it possible to produce alcohols from almost any sugar- and starch-containing vegetable raw materials. The process of producing ethanol consists of various technological operations:

- preparation and grinding of raw materials;
- fermentation using highly active alpha-amylase enzymes using bioengineered method;
- formation of pure ethanol in distillation columns.

The wastes of industrial production of alcohol are stillage and fusel oils. Stillage can be used in the production of forage.

Hydrolytic (technical, wood-based) ethanol is synthesized from raw materials containing cellulose. Cellulose is a carbohydrate, a polysaccharide having the formula $(C_6H_{10}O_5)_n$. It is a linear homopolymer of hundreds and even tens of thousands of D-glucose residues. Glucose can be made by hydrolysis of cellulose (3) in the presence of sulfuric acid (H_2SO_4):

$$(C_6H_{10}O_5)_n \text{ (cellulose)} + nH_2O \rightarrow nC_6H_{12}O_6 \text{ (glucose)}. \quad (3)$$

Sulfuric acid must be removed (for example, by sedimenting with limestone). Ethanol is obtained by yeast fermentation of sugars produced as a result of cellulose hydrolysis. A ton of timber yields up to 200 l of ethanol.

Initially, methanol was made from a hydrated distillate extracted in the process of dry distillation of timber (heating of timber without oxygen access). The methanol produced in this way contained various difficult-to-separate impurities (in particular, acetone).

The catalytic synthesis of methanol (synthetic alcohol) from carbon monoxide and hydrogen, occurring under pressure and the use of catalysts, has reached an industrial scale. Currently, the main amount of methanol is produced on the basis of natural gas synthesis [7].

A promising direction for obtaining methanol from renewable resources is the cultivation of marine phytoplankton, further biosynthesis of methane by methanobacteria, and subsequent catalytic conversion to methanol. The following factors has prompted the development of this technology: a high rate of growth of phytoplankton biomass (up to 100 t/ha of seashore per year); no need to use fertile soils and fresh water; no competition with food production; high energy balance of methanol production using this technology (reaches seven).

Butanol can be made from renewable vegetable and mineral raw materials. It is produced from renewable vegetable raw materials as a result of bioconversion, which proceeds with the participation of bacteria belonging to the genus *Clostridium* [3]. This process is known as acetone-butyl fermentation. The raw materials for the production of butanol, as well as for ethanol, are sugar- and starch-containing agricultural crops, as well as cellulose-containing plants.

Butanol used as a motor fuel has better properties than ethanol. Restraining factors for its use are a lower yield of butanol per 1 kg of vegetable raw materials compared to ethanol and, accordingly, its higher cost. Currently, selective breeding studies of other bacterial strains are being conducted, and new technologies are being developed to increase the yield of butanol [8]. It is possible to increase the scale of butanol production quite quickly: it is based on the same raw materials as the production of ethanol, therefore, the use of existing equipment of distilleries is acceptable.

Output of Alcohols from Various Raw Materials

The renewable vegetable raw materials for the production of alcohols are various food and non-food crops containing sugars, starch, and cellulose in their structure.

Some plants (sugar cane, sugar beet) accumulate large amounts of sugar; others (cereals, potatoes, cassava, sweet potatoes) accumulate starch. Sugars and starch are a source of energy for humans and many animals.

In Brazil, sugar cane is considered the main raw material from which ethanol is produced, in the USA it is corn. In Europe, grain crops are used for this purpose, as well as sugar beet (its share in the production of this alcohol is more than 20 %).

Non-food vegetable plant raw materials used as raw materials for the production of hydrolysis alcohols include wood and its various wastes, as well as plant residues after growing and processing crops [9], a number of perennial herbaceous plants (for example, miscanthus, whose yield (15–20 t/ha) is preserved for 20 years or more).

Table 3 shows the values of ethanol output from carbohydrates. Plants contain various carbohydrates (in particular, sweet potato contain up to 30 % of starch and up to 6 % of sugars).

When processing different raw materials, the average output of ethanol from 1 ha of sown area is different. Table 4 shows the average values of alcohol output from various raw materials. The results may differ depending on the crop variety, processing conditions, production technology, etc.

The use of modern innovative farming technologies allows to get high yields. Thus, 100 tons or more of sugar beet can be harvested from 1 ha of sown area, which is equivalent to 10,000 l of ethanol.

Table 3 – Ethanol output from 1 kg of carbohydrates

Carbohydrates, 1 kg	Formula	96 % ethanol, l
Starch	$(C_6H_{10}O_5)_n$	0.59
Sucrose	$C_{12}H_{22}O_{11}$	0.56
Glucose (fructose)	$C_6H_{12}O_6$	0.53

Table 4 – Ethanol output from 1 kg of food raw materials

Raw material, 1 kg	96 % ethanol, l	Carbohydrates, %
Peas	0.31	49
Buckwheat	0.38	60
Potato	0.1	17
Corn	0.41	65
Oats	0.38	60
Wheat	0.38	60
Millet	0.38	59
Rice	0.48	75
Rye	0.35	55
Sugar beet	0.098	17.5
Barley	0.37	58

Use of Raw Materials and Waste from the Production of Alcohols for the Production of Food and Fodder Products

An important special feature of the production of alcohols is its dependence on the type and quality of raw materials, as well as the significant material intensity of the technology: 60–70 % of the cost of alcohol falls on raw materials. There is a question of rational use of the resulting secondary raw materials, which makes it possible to increase profitability, production safety, and environmental friendliness; to obtain nutritious feeds containing a set of valuable macro-, micro- and ultra-microelements.

When processing vegetable raw materials during fermentation, a converter mash is created, which is characterized by a complex composition. It includes water, alcohol, and various organic and inorganic compounds. The composition and content of the components of the converter mash depends on the type of raw material used, as well as its quality, technology, and processing modes.

The predominant waste of alcohol production is stillage. It remains after the extraction of alcohols from the converter mash and is a light brown aqueous solution containing nutrients. Depending on the production technology, 10–15 l of stillage account for 1 l of alcohol, dry substances in it make up 5–10 %.

The implementation of a complex resource-saving technology for alcohol production involves various options for processing stillage in order to obtain protein-carbohydrate products for food and fodder purposes (Figure 1): food fermented fiber, fodder yeast, protein-vitamin concentrates, premixes, dry stillage [10]. Their introduction into the diet of animals and poultry provides an increase in meat productivity by 10–15 %, an increase in the safety of young animals, growth in milk yields from cows, and egg production from birds.

An important component in the implementation of a complex resource-saving technology for the production of alcohols is vegetable raw materials. A plant used as a raw material for the production of alcohols should have a high yield, contain a large amount of carbohydrates (sugars, starch or cellulose), have a short ripening period, make it possible to use all its parts in complex processing.

Sugar beet is ideal for all of these criteria. It has a high yield (100 tons or more of sugar beet per hectare of cultivated area, which is equivalent to 10,000 l of ethanol). Its root vegetable contains up to 23 % of sugars. In September, by the beginning of harvesting, the mass of sugar beet leaves is 30–100 % of the mass of root vegetables. The green mass is rich in protein and other useful substances; it can be directed to livestock feed. Nutritionally, it is not inferior to sown grasses: 5–6 kg of green mass corresponds to one feed unit.

Table 5 shows the composition of various parts of sugar beet. The chemical composition and sugar content can vary significantly depending on the growing conditions.

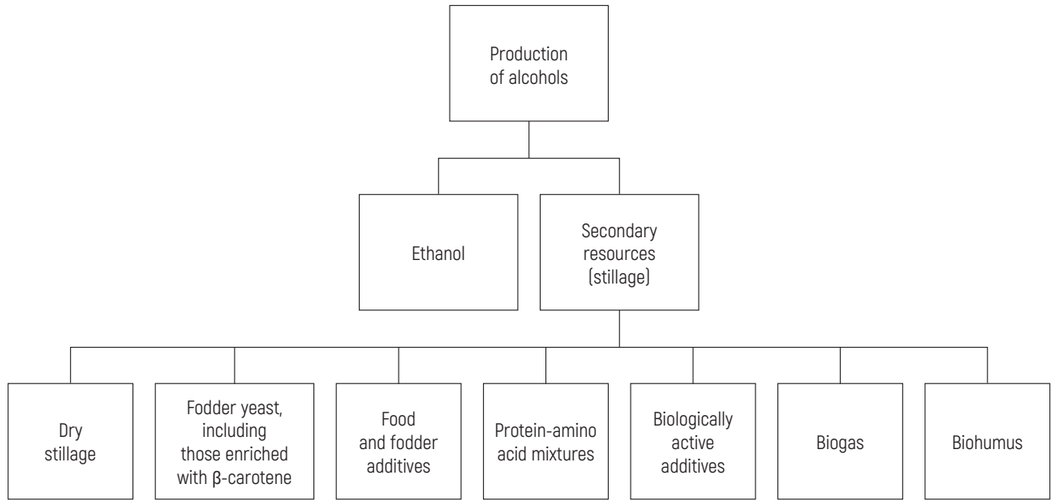

Figure 1 – Diagram of complex processing of raw materials for resource-saving technology of alcohol production

Table 5 – Composition of root vegetables and leaves of sugar beet [11]

Components	Content in 100 g of natural product, g		Content in 100 g of dry matter, g	
	Root vegetable	Leaves	Root vegetable	Leaves
Dry substances	23.6	13.85	100	100
Sucrose	16.5	–	69.91	–
Raw protein	1.05	2.41	4.45	17.4
Raw fat	0.12	0.19	0.51	1.37
Raw fiber	1.16	0.78	4.91	5.63
NFE* (except sucrose)	2.92	6.88	12.37	49.67
Ash	0.75	2.75	3.18	19.85

* NFE – nitrogen-free extractive substances (sugars, starch, and other soluble compounds used by the body for energy needs).

Sugar beet can be converted into sugar; its average yield will be 12–13 %. In the production of sugar from beets, by-products are obtained (Table 6).

Table 6 – By-products, % by weight of processed sugar beet

	Raw beet pulp	Molasses	Filtration sludge
By-products, %	80–83	5–5.5	10–12

Beet pulp (desaccharified chips) is the main by-product in the production of sugar. It is characterized by high nutritional value, contains a lot of fiber, is a ready-made feed for cattle. The pectin available in the pulp increases the digestibility of the feed. It is used raw; it is easily siloed, dried, and granulated. In dry form, 100 kg of pulp corresponds to 85 feed units, which is close to concentrated feeds.

Molasses is another important by-product in the production of sugar, similar to dark brown syrup. It includes 58–60 % of sugars, a significant amount of nitrogenous substances, NFE, etc. Molasses is used in the production of ethanol, yeast, compound feeds, serves as a nutrient medium for obtaining vitamin B_{12}; mixed with other components, it is directed to livestock feed.

Filtration sludge is created after cleaning beet juice with lime; it has a humidity of 30–50 % (depending on the filtration technology). It is useful as a fertilizer for soil with high acidity, improves its structure. It can be used in the production of building materials (silicate bricks, cement).

Energy Balance of Alcohols

The production of alcohol from renewable vegetable raw materials consists of several stages: planting and growing crops, harvesting, preparation and processing of raw materials, waste disposal. These steps require appropriate resources and infrastructure. The ratio of the energy obtained by burning fuel to the energy expended in the process of its production is known as the energy balance of fuel.

This indicator is a criterion for assessing the ability of biofuels and alcohols to serve, in particular, as a substitute for non-renewable energy sources. Numerous studies and publications show that the results obtained can vary greatly and sometimes even have contradictory conclusions. Figure 2 shows information about the energy balance of ethanol taken from various sources.

The energy balance of ethanol depends on the type of plant culture from which alcohol is produced, the efficiency of farming methods, yield capacity, and other factors (Table 7). Practice shows that even with the same initial raw materials, the energy balance will be different. There are several reasons for this. Differences in surveys may arise at each of the stages: determination of the system, inventory of the life cycle, impact assessment, interpretation and analysis of the results [12].

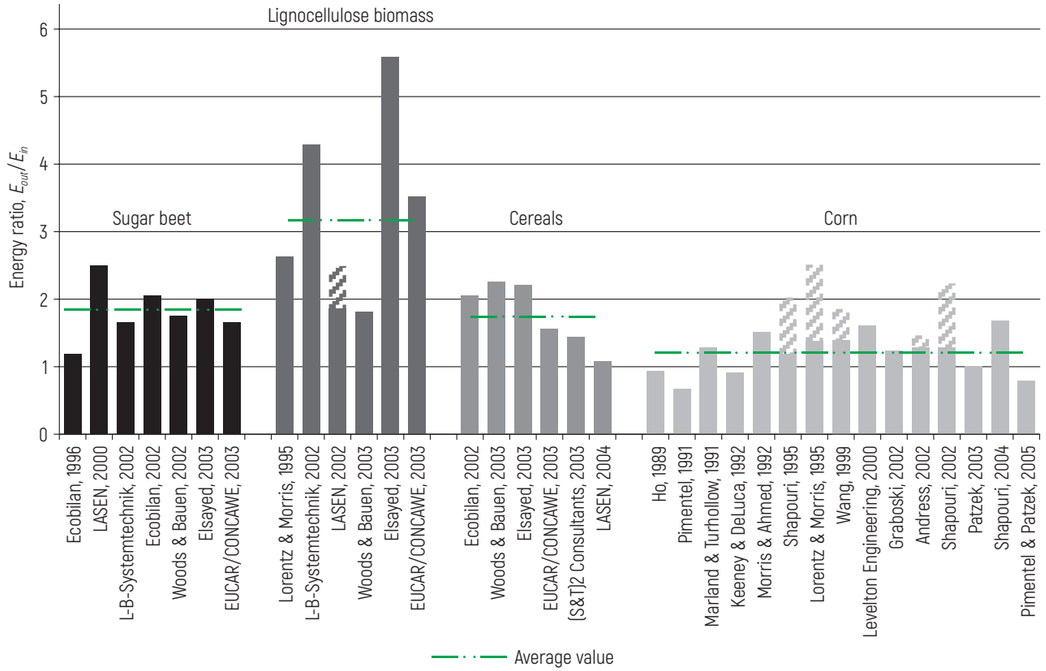

Figure 2 – Energy balance of ethanol obtained from different raw materials [12]

Table 7 – Factors affecting the results in the study of the energy balance of alcohols [12]

Factor	Determination of the system	Inventory of the life cycle	Impact assessment	Interpretation and analysis of the results
1	2	3	4	5
Time frame		+		
Geographical location (climatic factors)	+	+		

End of Table 7

1	2	3	4	5
Farming methods		+		
Mechanization		+		
Type of fertilizer (organic, mineral)		+		
Yield capacity, output of alcohols from 1 ha of sown area		+		
Raw material quality	+	+		
Type of raw materials (sugar/starch/cellulose)		+		
Type of raw materials (harvest/waste)	+	+		
Delivery of raw materials (distances, delivery method)	+	+		
The nature of the production enterprise	+	+		
Scale (commercial, pilot, pattern-making)	+	+		+
Technology, use of by-products		+		
Structure of the energy system		+		
Electricity production		+		
Electricity consumption		+		
Quality of life cycle inventory data		+		+
Reliability		+		+
Completeness		+		+
The nature of the study (bias)		+	+	+
Distribution of the load on the environment	+			+
Impact assessment method			+	+

The key factors affecting the energy balance of alcohols: methods of agriculture; crop yields; quality of raw materials, which determines the output of alcohols from 1 ha of sown area; processing of secondary resources of alcohol production; delivery of raw materials for processing.

Conclusion

Alcohols used as fuel provide a number of significant advantages. Obtained from renewable vegetable raw materials, they have a zero-carbon balance, i.e., they are neutral as a source of greenhouse emissions, unlike the products of petroleum refining. Alcohols have a positive energy balance (the amount of energy received from alcohols is more than that spent for their production). Their use in the composition of motor fuel reduces emissions of the main toxic components (carbon monoxide, unburned hydrocarbons, and nitrogen oxides), while increasing the efficiency of engines. The use of alcohols is characterized by a minimum duration of the carbon cycle.

The correct process structuring of alcohol production (assimilation of innovative farming technologies to achieve higher yields with lower energy costs, introduction of integrated resource-saving technology of alcohol production, reduction of costs for the delivery of raw materials for processing) will significantly improve the energy balance of obtaining alcohols.

All by-products created during the production of alcohol may be needed to feed the earthworm, as well as aerobic and anaerobic microorganisms for the formation of living humus – the basis of fertility of any soil. Thus, from 100 tons of sugar beet grown on 1 ha, after the production of alcohol, up to 50 tons of living humus can be obtained (with additional use of green beet leaves) worth up to 50,000 USD (at the rate of up to 1,000 USD/t), which exceeds the market value of alcohol itself, since the effectiveness of humus in improving soil fertility is greater than, for example, that of natural black soils.

This approach to alcohol production technology makes it biospheric and highly profitable. At the same time, a product made from vegetable raw materials and used as fuel does not increase the carbon footprint in the biosphere, since any plants on Earth's land in the process of natural biospheric metabolism are inevitably converted into humus (no matter in the soil or through the stomachs of animals, for example, cows) with the release of carbon dioxide in approximately the same amounts as when alcohol is burned.

The development of alternative energy sources using renewable raw materials will make it possible to solve the energy and environmental problems of mankind. The use of plants in the production of biofuel, in particular alcohols, the introduction of integrated technologies for processing raw materials to simultaneously produce biofuel, animal feed, human food, and organic fertilizers for plants will create an enclosed and biospherically balanced food solar bioenergy.

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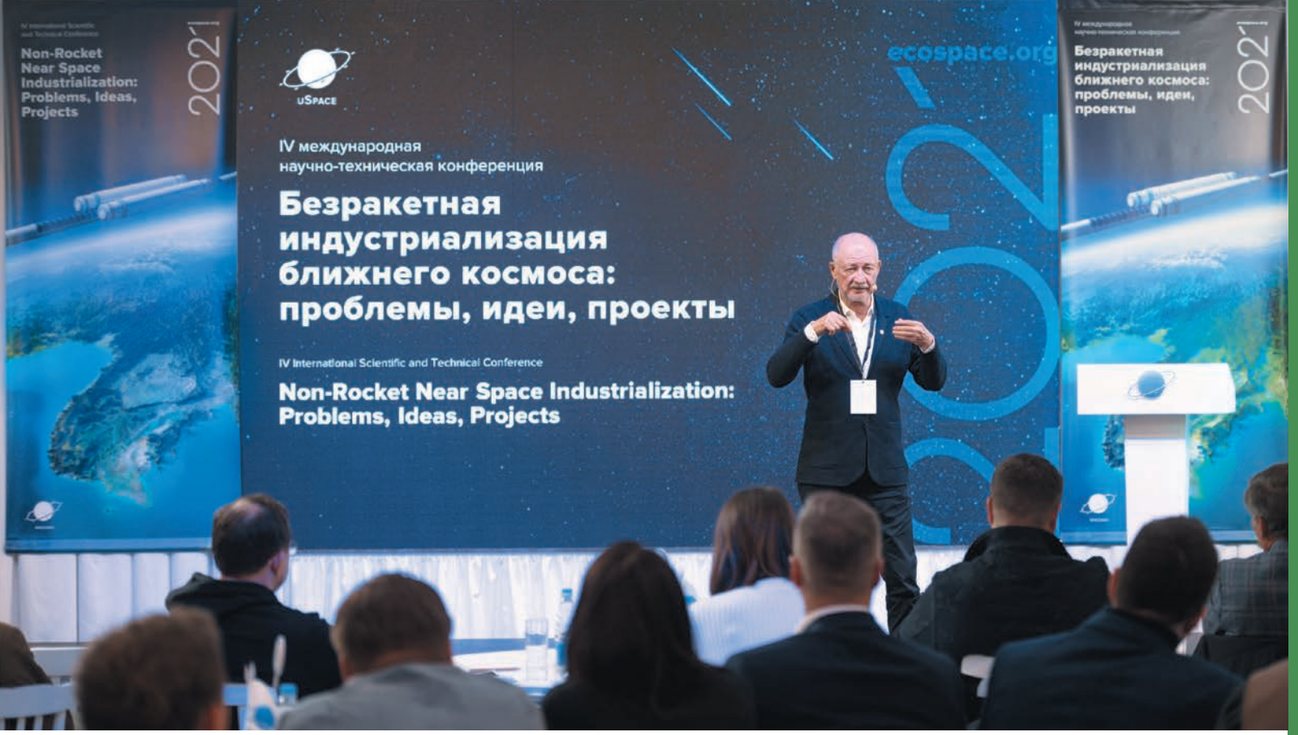
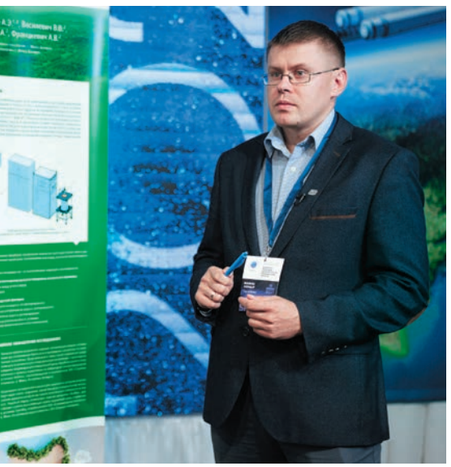




Resolution of the IV International Scientific and Technical Conference “Non-Rocket Near Space Industrialization: Problems, Ideas, Projects”

On September 18, 2021, Maryina Gorka (Republic of Belarus) hosted the IV International Scientific and Technical Conference "Non-Rocket Near Space Industrialization: Problems, Ideas, Projects".

The scientific agenda of the conference included plenary sessions, panel discussions, and poster sessions. The total number of reports submitted was 28. Scientists, researchers, and inventors from Belarus, Russia, Ukraine, Sweden, United Arab Emirates, Germany, Spain, Romania, and China showed great interest to the conference despite the coronavirus pandemic that sharply limited the communicability of people all over the world. Domestic and foreign representatives of academic communities, public and commercial organizations from Belarus, Russia, Ukraine, USA, Canada, Great Britain, Estonia, Slovakia, United Arab Emirates, Saudi Arabia, Ghana, and Congo took part in the conference.

The conference was held to summarize the results of research and practice work carried out in scientific and project designing organizations, design offices, and engineering companies, as well as by individual researchers and enthusiasts in the following areas:

- solving global biosphere problems of our time with geocosmic means;
- prospects of technological development of near space under the EcoSpace program under the motto: "Earth is for life. Space is for industry";
- arrangement of large-scale cargo and passenger flows on the Earth – Near Space – Earth route, ensuring operation of the space industry in the interests of mankind;
- principles of creation, design, theory, and calculation of transport and infrastructure geocosmic complex – Unitsky's General Planetary Vehicle (GPV);
- design features, finding biological and ecological solutions to ensure the sustainable functioning of the Earth's biosphere and preserve biodiversity on planet Earth, as well as to develop hard-to-reach areas with adverse conditions for human life;
- particularities of creating linear cities (including the Equatorial Linear City) as integral components of the uNet communication network, based on uST transport and infrastructure complexes (up to 600 km/h) and uMach (up to 1,500 km/h), as well as erection of the ground infrastructure of the GPV and its takeoff and landing overpass (uWay);
- implementation of the EcoSpace program in order to consolidate the efforts of the global community to ensure the sustainable development of Earth's technogenic human civilization, as well as the coevolution of man and nature and the resetting of Earth's industry towards the biosphere vector of development.

Based on the results of the IV International Scientific and Technical Conference "Non-Rocket Near Space Industrialization: Problems, Ideas, Projects" the organizing committee and the participants have reached a number of important decisions.

1. To note the extremely high importance of further advance in the topic of large-scale near space exploration and resetting of Earth's industry towards the biosphere vector of development, including space.

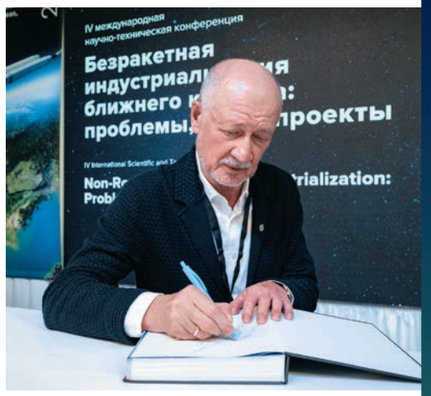
2. To emphasize the importance of the global geocosmic project – the General Planetary Vehicle – as the only possible one from an engineering point of view, and hence the key transport and logistics solution for the industrial development of near space and the implementation of the EcoSpace program.

3. Given the scale and significance of the work presented at the conference, to point out the paramount importance and obvious urgency of the development of cooperation between the countries, international organizations, the leading global companies, research organizations, and universities in order to implement the EcoSpace program.

4. To indicate that at present humanity is in the conditions of "civilizational socio-technogenic fork", which means we really have a choice. Either in two generations the traditional vector of technogenic development will lead our children and grandchildren to the point of no return for the entire mankind, its degradation, extinction, and death. Or we implement the EcoSpace program: relocating industry into near space, solving environmental, economic, and social problems on Earth and turning the planet into a blooming garden, where 10 bln people and more can live and work with comfort and safety.

5. To mark that the minds of millions of modern people have a destructive mixing of social and technogenic civilizational concepts (such as, for example, "limits of economic capacity of the planet" and "limits of economic activity of the world capitalist system"). In particular, this is expressed in the suicidal "5D" program imposed by the world pseudo-elite on all mankind: deindustrialization of the world economy (through its decarbonization) and depopulation of mankind (through its desocialization and digitalization).

6. To emphasize that social criteria of life activity of the Earth's technogenic human population (such as humanity, morality, humanism, ethics, culture, self-knowledge, self-development, spirituality, improvement of human-nature



relations) are more important than purely technogenic digital criteria (such as economy, money, profit, investment, ecology, innovation, technology, etc.) in choosing the ways of human evolution. Any immoral and spiritless civilization that any planet (including the Earth) would give birth to and nurture would inevitably perish if it focuses only on the unrestrained growth of the economy. This is exactly the logic in which a cancer cell exists: born of a healthy organism and nevertheless oriented by its immoral (in relation to this organism) criteria only towards its own rampant growth, it first destroys the limited resources of its host, creating metastases, and then kills it and dies itself along with the metastases. Humanity must not become such a cancerous cell for the Earth's biosphere. We, who live now, have this responsibility to our descendants, our children and grandchildren.

7. To introduce into the schedule of the conference a section called "Social and Moral Criteria of the Technogenic Development of Civilization and the Industrialization of Space". This means that our conference, as opposed to the existing destructive world platforms (such as the Club of Rome and the World Economic Forum in Davos, which promote deindustrialization, depopulation, and other similar "Ds" of our technogenic civilization) will be the only alternative platform in the world. Thanks to it, in the Belarusian town of Maryina Gorka, not only criticism of the imposed suicidal models of the civilizational structure will be heard but also alternative life-affirming civilizational models of development will be worked out and offered to all mankind, such as:

a) rapid industrialization of the world economy through innovative biosphere technologies, including those by relocating the hazardous part of industry into space;

b) recognition of the natural growth of the world population as an inevitable fact at this stage of civilizational progress. We do not intend to accept any measures to depopulate humanity, regardless of region, continent, or level

of development of the country, because we understand that our planet can "feed, provide clothing and shoes" for 10 bln people and more;

c) search for engineering, economic, and social solutions that contribute to the creation of comfortable, safe, and sustainable living conditions on planet Earth for at least 10 bln people for millennia by switching over to biosphere ecotechnologies in agriculture, power engineering, industry, transport and the settlement of people in linear eco-cities, organically integrated into the live nature and secured with everything needed – organic food, spring (artesian) drinking water, clean air, decent and well-paid work, revitalising rest, and moral entertainments;

d) further development of socialization and spirituality of human civilization, which differs from other terrestrial and extraterrestrial civilizations (such as dolphins and artificial intelligence, including the bio-digital convergent) by the fact that it is human beings in their flesh, blood, and spirituality who are the basic element and foundation of our civilization, as well as the planet industry created by them. In turn, the Earth's industry is the basic value of the technological (engineering) vector of human development, chosen by our ancestors thousands of years ago, from which we should not (and even more so not obliged to!) turn away for the benefit of anyone. To achieve this goal, it is necessary to strengthen traditional social human values that were historically developing for many centuries, such as family, society, culture, religion, language, etc;

e) improvement of the planet that gave birth to us and created in its biosphere all conditions for the emergence and rapid development (including social and technological) of Earth's technogenic civilization with 8 bln human personalities using the following biospheric methods:

- increase of natural soil fertility on all continents and in all countries, as well as the transition of global agriculture solely to natural organic farming;
- use of engineering technologies (including power generating ones), the waste of which will make living fertile humus and other organic components of the Earth's biosphere;
- construction of linear cities capable of providing themselves with everything necessary for life, work, and recreation, with an increase in the area of fertile land on the construction sites of such cities;
- arrangement of environmentally friendly and highly efficient "second level" transport and energy-information communications based on Unitsky String Technologies, which are the technological foundation of transport and infrastructure complexes – high-speed (uST) and hypervelocity (uMach) ones.

8. To recommend to Astroengineering Technologies LLC and the International Foundation "EcoSpace" to organize work on the support and financing of R&D as part of the EcoSpace program, including such projects as the General Planetary Vehicle, EcoCosmoHouse, Industrial Space Necklace "Orbit", uSpace, Unitsky String Transport (including for use in Earth orbit and on other planets), uNet transport and infrastructure network, uST transport and infrastructure complex, uMach transport and infrastructure complex, uCity (including the Equatorial Linear City), etc. For this purpose, it is necessary to attract various organizational structures, regardless of their form of ownership, as well as funds from private investors.

9. To hold regular scientific, technical, and practical workshops in this area, to attract a wide range of researchers involved in the problems of industrial development of near space.

10. To emphasize the high scientific and technical level of the reports submitted at the conference.

11. To publish a collection of conference materials. Participants, whose reports will be published, should arrange their works in the form of scientific articles in accordance with the specified requirements.

12. To conduct the next V International Conference on the problems of non-rocket exploration of near space in 2022 in the Republic of Belarus.

The Organizing Committee expresses its gratitude to all the participants, speakers, foreign guests, as well as sponsoring organizations and individuals who made the conference possible: Astroengineering Technologies LLC and Unitsky String Technologies Inc.; Unitsky's Farm Enterprise, which provided the venue and extensive assistance in holding the event that is significant for all mankind and intended to substantiate and demonstrate in practice the vector of the most sustainable development of our Earth's technogenic civilization in the foreseeable future: "Earth is for life. Space is for industry".

Organizing Committee
18.09.2021

Glossary: Terms and Definitions Mentioned in the Collection

Abbreviation **uST** stands for the central brand of Unitsky Group of Companies (UGC); it combines the names of Unitsky String Technologies, the parent engineering company Unitsky String Technologies Inc., and uST transport and infrastructure complex / Unitsky String Transport as the physical embodiment of uST transport and infrastructure solutions.

Active protection system (APS) is a generator of electrostatic field where negatively charged debris of space garbage create resonant vibrations in it.

Artificial atmosphere is a specially selected mixture of gases, which ensures regular breathing and gas exchange in living organisms, including humans, who are in an enclosed ecosystem; has the same quality as the Earth's atmosphere. The gas component of the EcoCosmoHouse space is an artificial atmosphere.

Biofuels are various types of combustible products derived from plant raw materials. Their main advantages are renewability and accumulation of solar energy coming to the Earth.

Biological balance is the preservation of dynamic stability of natural complexes (biogeocenoses) over a long period of time, i.e., relative balance of stability of species composition, number, and productivity of living organisms.

Biological diversity is the natural diversity of life in every manifestation, as well as an indicator of the complexity of the biological system, the diversity of its living components. Biodiversity is considered at the hierarchical levels of life organization with the following main ones: molecular and genetic, organism and species, biogeocenotic, and biosphere.

Civilization technogenic fork is a stage of development of the Earth's technosphere, which, when achieved, makes the technogenic human civilization face with a historically important choice of two mutually exclusive scenarios of action:

1) Earth's civilization continues to develop conventional technogenic vector, limited only by the planet size and resources. At the same time, resource consumption does not change dramatically because the world economy relies on obsolete and resource-intensive technologies (primarily, century-old transport and logistics technologies). As a consequence, the point of no return from degradation, extinction, and death of human civilization will come in about two generations (in the third quarter of the 21th century);

2) the beginning of near space industrialization, gaining access to its unlimited resources, infinite space, matter, and energy, as well as new technological resources: weightlessness, deep vacuum, technological purity (without dust and microorganisms), and cosmic rays. Mandatory requirement: inefficient transport and infrastructure technologies, power industry, habitat (cities), infrastructure, and agriculture used on the planet, which pose the greatest threat to the Earth's biosphere, must be replaced with better communications and eco-oriented technologies.

EcoCosmoHouse on Planet Earth (ECH-Earth) is a structure on Earth designed for autonomous and unrestricted long-term residence of a human settlement with calculated density. The inner enclosed space of ECH-Earth has conditions for the development of ecosystems, has a necessary set of the planet's biosphere properties in this regard, and additional technological processes that are modeled to ensure human needs for existence (parameters of the atmosphere and habitat, food resources, etc.). ECH-Earth is an Earth biosphere model of the space ECH in terms of creation and arrangement of internal space and all relevant components (biosphere, technologies, process interconnections, etc.) with an enclosed cycle of matter (living and mineral), energy, and information.

EcoCosmoHouse technological platform (ECH) is the construction in outer space of buildings with an internal habitable space, isolated from the external aggressive cosmic environment. Inside ECH, there is an enclosed ecosystem of the Earth's type, including artificially produced gravity, living fertile soil, flora and fauna (including microflora and microfauna), and atmosphere with adjustable parameters (temperature, humidity, etc.) for unlimited long-term, autonomous, eco-comfortable living and activity of both individuals and groups of them and many thousands of settlements in equatorial orbits of the planet, as well as in open near space and deep space.

EcoHouse technological platform is an eco-oriented construction of residential and industrial buildings and structures on Earth with adjacent space open to the external natural (biosphere) environment, filled with natural and cultural (organic farming) ecosystems, in which atmospheric, soil, and water parameters are regulated by the Earth's nature. The soil from under the buildings during their construction is transferred to the roofs and floors to be then enriched with living humus. This greening is based on the principle that all construction on the planet is meant to increase the area of fertile soil and its fertility.

EcoSpace is the program to provide for the development of eco-oriented biosphere technologies in order to transform the main sectors of Earth's industry, infrastructure, power industry, transport, and agriculture. It assumes bringing the hazardous part of the Earth's industry out into near space to secure the balance in a perfect world represented by BioSpace, TechnoSpace, and HomoSpace triunity of program, which together form a complex of optimal conditions for sustainable growth and further development of anthropogenic Earth's civilization in cosmic direction.

BioSpace is a restored and balanced planetary biosphere ecosystem open to space that includes the Earth's humanity, which no longer experiences the devastating man-made effects of Earth's technosphere and continues to evolve by the laws of evolutionarily established terrestrial nature. It includes:

- natural and cultural (organic farming) ecosystems on the planet land, including aquatic ones (lakes, rivers, etc.);
- oceanic, marine, and atmospheric ecosystems with the possibility of eco-friendly external control of weather, climate, and other systems of the planet through natural methods;
- flora and fauna of terrestrial and aquatic ecosystems (including microflora and microfauna) with their biodiversity preserved and currently available;
- Earth's humanity with each individual being healthy and happy.

TechnoSpace includes newly created industrial components:

1) Earth's industry which is based on novel eco-oriented technologies and consisting only of the technological industries necessary for humans within the Earth's biosphere;

2) space industry, including energy-consuming, resource-intensive, hazardous, and other industries that are moved outside the Earth's biosphere, which acquire an absolute competitive price and quality advantage as part of the space technological environment;

3) GPV geocosmic transportation complex, providing environmentally friendly transport and logistics link between the Earth's and space components of the industrial TechnoSpace with cargo, energy, information, and passenger flows of industrial scale;

4) artificial intelligence to manage the above components 1–3 under the multilevel control of the HomoSpace.

HomoSpace is an advanced world socio-political system based on the consolidation of the international community of biological humans (but not digitized convergent biorobots) around a single governing center accumulating the territorial, financial, economic, scientific, human, military, and political potential of all participating countries. This will open the gate to inexhaustible and accessible resources of space and through space-oriented economy of the technogenic civilization on Earth will create new socio-political and economic conditions for the most complete implementation of sustainable development of biological mankind, including social justice, equality, freedoms, harmonious development, as well as the right of every inhabitant of the planet for a worthy long and happy life. HomoSpace is developed and governed by people using artificial intelligence as an assistant and advisor (but not a leader). The main value of HomoSpace is the humane attitude of Man and his spirituality as a socio-biological quintessence created by the Universe (God) as a result of billions of years of evolution of life in the space home named Planet Earth.

Ecosystem is a biological system (biogeocenosis) consisting of a community of living organisms (biocenosis),

their habitat (biotope), as well as a system of connections that exchange substance and energy between them.

EcoTechnoPark is a demonstration and certification center for uST transport and infrastructure solutions in the Republic of Belarus (Maryina Gorka).

Equatorial Linear City (ELC) is the Earth's component of geocosmic transport and communication complex which locates the uWay with the whole infrastructure required for the GPV to fly and for servicing global geocosmic cargo and passenger flows. This city represents a harmonious blend of cluster settlements with the natural environment of land and ocean areas of the planet. The settlements are interconnected with uST tracks and stretch along the equator.

Food solar bioenergy (FSBE) is power industry based on the integrated consumption and processing of biomass of greenery that has absorbed the energy of the Sun, to produce biofuels, animal feed, and food for humans.

General Planetary Vehicle (GPV) is a geocosmic reusable torus-shaped spacecraft for non-rocket near space industrialization encircling the Earth in the equatorial plane; it ensures industrial cargo and passenger flows (millions of tons and millions of passengers per year) from the Earth to near-Earth equatorial orbits and back; based on the only possible (from the point of view of physics) environmentally safe and energy-efficient geocosmic transportation technology which uses only internal force of the system and electric energy.

GPV overpass (uWay) is a takeoff and landing, energy, and communication overpass hub for geocosmic transportation, located along the equator and combined with an eco-settlement of new generation.

Industrial Space Necklace "Orbit" (ISN "Orbit") is a multi-orbital transport, infrastructure, and industrial-residential complex serving Earth's humanity and covering the planet in the equator plane. It is a functional analogue of the Equatorial Linear City, however located in space, as well as a range intended to protect from space threats (including meteorites) and a platform for the Earth's civilization expansion into deep space.

Linear city (uCity) is a cluster pedestrian urban settlement with its ground surface intended for people, animals, and greenery; the development of residential, administrative, and industrial clusters is implemented through the eco-oriented technologies EcoHouse; electricity and heat are supplied by the uEnergy technology; food supply is linked to the technology of organic farming uGreen. Transport, energy, and information communications are arranged above ground on the second level (elevated version) according to the uST technology. Linear cities are characterized by the absence of devastating man-made effects on the biosphere, high efficiency of urban economy, and its autonomy, as well as decent quality of life and working conditions for each resident.

Relict solar bioenergy (RSBE) is power industry based on the use of fossil brown coal and shale to produce clean energy and form living humus, which is necessary to restore the fertility of various types of soils.

Space-based solar power plant (SBSPP) is an orbital solar power plant using solar energy; it provides energy independence and biospheric environmental safety of the ISN "Orbit".

Space industrialization vector is a global re-equipment of the Earth's technosphere to eliminate its devastating man-made effects on the Earth's biosphere by transferring hazardous, energy- and resource-intensive industries into near space on low-Earth orbits. The space industrialization vector is also about using eco-oriented technologies to modernize that part of industry still on Earth and functioning in the biosphere.

Sustainable development is "the development that meets the needs of the present without compromising the ability of future generations to meet their own needs" – this concept was formulated by the UN World Commission on Environment and Development and is the basis of the UN goals and principles.

uEnergy technological platform is designed to generate green electric and thermal energy using:

- specially equipped thermal power plants for eco-friendly combustion of brown coal, shale, peat, and other raw materials of organic origin in order to produce living fertile humus from their combustion waste;
- renewable energy sources, namely the solar energy on Earth and in space, as well as the energy of wind and sea currents;
- "hydrogen – oxygen" pair as a fuel accumulator for the optimization of the planet power industry and space transportation.

uGreen technological platform is organic farming in a new logic of recreation and intensification of natural biosphere processes by direct borrowing and using natural soil ecosystems with their microflora, microfauna, and biogeocenosis, as well as in the logic of a complete rejection of any synthetic chemicals (fertilizers and plant protection agents), technologies of genetic modification, and other elements of traditional intensive farming.

uMach is the concept of a hypervelocity vehicle as a part of uST transport and infrastructure complex. It is designed to travel at speeds over 1,000 km/h inside a forevacuum tunnel (with artificially reduced atmospheric pressure) to provide high-speed transportation for long (from 200 km) distances.

uNet transport and infrastructure network is an international transport, energy, and information communication network created on the basis of uST transport and infrastructure solutions along linear cities.

uSpace geocosmic program is a program of non-rocket near space exploration by means of the General Planetary Vehicle, which will preserve the biosphere by taking the industry (technosphere) outside the planet Earth (outside the Earth's biosphere).

uST technological platform is the construction (along linear cities) of a new kind of transport, infrastructure, energy and communication networks uNet, created on the basis of prestressed (string) Unitsky's structures. It is designed to provide all necessary communication links between objects (and continents) on Earth; between objects in near space moving on circular equatorial orbits; between objects on Earth and those deployed in near space.

uTerra is a biohumus produced from brown coal, ash, organic raw materials, inoculum, and aerobic microorganisms to increase fertility and improve the quality of soils.

Reviews for the Collection of Articles of the IV International Scientific and Technical Conference “Non-Rocket Near Space Industrialization: Problems, Ideas, Projects”

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The real progress of mankind should begin with a civilizational reboot.

There was a 33-year journey between the first and the fourth conferences devoted to non-rocket near space industrialization. This time was the development of engineer A. Unitsky's concept of the General Planetary Vehicle (GPV) as an alternative to near-Earth space exploration by rockets. His global project was transformed over the years into an engineering development of such a huge scale, which the world had not yet known. All these decades A. Unitsky followed a persistent, consistent, methodical, comprehensive, and scientific approach in the development of the GPV concept, gathered creative teams, looked for and convinced investors, put into practice the future-oriented innovations, justified the harmful consequences of the existing industrial and technological way of human civilization development, proved the prospects of relocating the entire production and technological infrastructure into near space by means of the GPV, offered and implemented technologies for our planet transformation into an ecologically balanced environment for the humans to live and thrive.

Each of the four conferences held by A. Unitsky since 1988 is a notable step in the systemic movement towards the aforementioned noble goals. The materials included in this collection are no exception.

Historically important information is given in the opening speech of A. Unitsky. Once again, he emphasized that the “industrial vector of development is heading towards a dead end”. The real progress of mankind should begin with a “civilizational reboot”, and the starting point in this process could be the string-rail transport and linear cities built along the designed GPV equatorial overpass.

The welcome speeches by distinguished scientists and experts from a number of countries published in the collection demonstrate that A. Unitsky's ideas are increasingly gaining ground and finding new supporters who are able to think on a large scale and without any political veil.

Unlike the previous ones, this collection contains a significant number of articles focused on the analysis of the limits in the development of technocratic civilization and ways to reassess them. It is appropriate to point out that the participants of the fourth conference had the opportunity to get to know the original book by A. Unitsky “Civilization Capacity of the Space Home Named Planet Earth”. The most important points of this publication are well reflected in the peer-reviewed collection.

It is symbolic that both A. Unitsky and his genius idea of the GPV were born in Belarus – an island of stability, humanity, and reason on a planet torn by contradictions, on which a significant part of the political leaders of famous countries have gone mad and are blindly leading us all to nuclear war.

GPV-scaled project requires scrupulous and scientifically grounded consideration of a huge number of materials science, technological, ecological, financial, legal, political, cosmological, biological, biochemical, medical, agricultural, energy, and even linguistic aspects. All of the above is included to some degree in the conference proceedings collection. The study of its content and comparison with previous issues shows how consistently and comprehensively the GPV concept is developing. This analysis demonstrates a fairly clear vision of the GPV idea author, A. Unitsky, about the further, surely thorny ways of promotion and implementation of the project, bringing hopes of mankind for peace, prosperity, and progress on planet Earth and in the near space.

A. Busel,
Chief Researcher of the RUE "BeldorNII",
Doctor of Technical Sciences, Professor

The results of these works will serve as the basis for new discoveries in fundamental and applied science.

The materials of the collection show that modern trends in the development of civilization lead to the fact that the technosphere created by humans negatively affects the eco-sphere of the planet Earth. Such an impact is due to consumer attitudes towards natural resources, which are regarded as a source of profit. This leads to inefficient use of human and natural potential, provokes social, economic, and political conflicts, often turning into a military paradigm. These problems do not contribute to the progressive development of society, do not increase the standard of living of the planet population, but become the source of confrontation both among people and between people and nature.

At the same time, the process of identifying and analyzing these problems allows us to propose ways to solve them. One of the options is the structural transformation of the technosphere containing artificial technical objects that are manufactured and used by humans (for example, closely interacting industry and transport, which are key system–forming elements).

The research by A. Unitsky and his associates, published in the collection, demonstrate that they have chosen a progressive vector for the development of civilization. The main stages of this course will be able to change the traditional and largely inefficient processes of production, transport, and consumption. The combination of these elements in a new format is possible by means of the General Planetary Vehicle (GPV), which allows to literally rise into near space and set up new efficient production facilities in the near-Earth orbit to implement traditional technological processes at a new technical level. At the same time, the terrestrial habitat can also receive a new development, focused on the cultural transformation of all aspects of human life.

Concurrently with the above, the joint participation of all the states of the planet in the global GPV project will help reduce political tensions between countries, optimize economic interaction, stimulate the exchange of technologies, and ultimately become a determining factor aimed at improving living standards.

The bold studies carried out by the authors require continuation and practical testing at the level of models and prototypes, allowing the proposed global project to be implemented in the future. Perhaps the results of these works will serve as the basis for new discoveries in fundamental and applied science.

That is why the tasks set by A. Unitsky's conference of scientists (engineers, ecologists, biologists, sociologists, economists, political scientists, etc.), whose developments will contribute to positive transformations of the planet technosphere and the practical attainability of space, can be considered achieved.

Lastly, I would like to wish the authors and A. Unitsky success in implementing their ideas and overcoming all the difficulties that may arise along the way, and that new conferences should take place and unite supporters and critics for the development of science and technology for the benefit of the planet Earth.

V. Tarasenko,
President of the Crimean Academy of Sciences,
Chairman of the Crimean Republican Association "Ecology and Peace",
Doctor of Geology and Mineralogy Sciences, Professor,
Honored Scientist and Engineer of the Republic of Crimea

The materials of the collection do not convey just ideas, dreams, and reasoning. This is an analysis of vast actual material, this is a daring aspiration to the stars in the 21st and following centuries!

I welcome the publication of the collection "Non-Rocket Near Space Industrialization: Problems, Ideas, Projects" based on the materials of the IV International Scientific and Technical Conference. I believe that this is a great event for a wide scientific, technical, ecological, philosophical, educational community, and in general for intellectuals of the planet, who think about its future sustainable development.

The articles presented analyze the consequences of the activities of the modern industrial and so-called post-industrial consumer society. Forests, the "lungs" of the planet, are shrinking, lands are being depleted, biodiversity is being lost, the ozone layer is being destroyed, and the climate is changing. Mankind has exceeded the permissible limit of disturbance of the biosphere, initiating the destruction of natural communities and ecological niches of many species and organisms, and has taken a path of unsustainable development, leading to the degradation of the natural environment. The ecological limit turned out to be the limit of economic growth.

The brilliant scientific and worldview ideas, thoughts, and philosophical and methodological generalizations of Academician V. Vernadsky expressed in the 20th century became the fundamental scientific basis of the noosphere project of socio-natural evolution, covering cosmic, geological, biospheric, anthropogenic, and social evolution. This great scientist was convinced that the general vector of future development depends on the productivity of the scientific minds.

Our remarkable contemporary – designer, engineer, ecologist, philosopher, natural scientist, Man of the planet Earth – A. Unitsky with his many years of titanic work and bright breakthrough in string transport, astroengineering technologies, non-rocket large-scale development of near space with relocation of industrial and even agricultural production to the Industrial Space Necklace "Orbit" is the convincing evidence that the state of human mind, ecological culture, and morality is a decisive factor in future cosmo-, geo-, bio-, and social evolution.

The materials of the collection do not convey just ideas, dreams, and reasoning. This is an analysis of vast actual material on the state of the biosphere and technosphere; this is a representation of trends in the development of the industry of human civilization; this is carrying out convincing calculations which serve the basis for a daring aspiration to the stars in the 21st and following centuries!

I perceive A. Unitsky as a Prometheus of our unstable era, full of all kinds of worries and threats. The planetary and cosmic thinking of the Belarusian scientist, his breakthrough in the knowledge of the natural world, society, as well as the depth of scientific substantiation of the path of sustainable development of the biosphere and civilization, will always shine to humanity and inspire new generations of researchers to serve the scientific truth and implement the scientific transformation of the biosphere into a true noosphere of planet Earth, and in the immediate future – into the noosphere of near and deep space.

Dear readers!

This collection was compiled by the results of the IV International Scientific and Technical Conference "Non-rocket Near Space Industrialization: Problems, Ideas, Projects" held in Maryina Gorka on September 18, 2021. We hope that the materials from this book were useful for you.

You can send your feedback and suggestions to: conf@ecospace.org.

Additional information on the topic of non-rocket space industrialization is available on the online resource: www.ecospace.org/ru/conferences.

Organizing Committee of the Conference
and Editorial Board for the Collection of Scientific Articles

Non-Rocket Near Space Industrialization: Problems, Ideas, Projects: Collection of Articles of the IV International Scientific and Technical Conference, Maryina Gorka, Sep. 18, 2021 / Astroengineering Technologies LLC, Unitsky String Technologies Inc.; ed. A. Unitsky. – Minsk: StroyMediaProject, 2022. – 384 p.
ISBN 978-985-7172-75-7.

The articles of the collection reflect the subject matter and content of the reports presented within the framework of the IV International Scientific and Technical Conference "Non-Rocket Near Space Industrialization: Problems, Ideas, Projects". At the 2021 conference, the ways of solving global problems of our time with geocosmic means were considered; the principles of designing a transport and infrastructure geocosmic complex were announced; the features of planning space settlements with the creation of enclosed ecosystems were outlined; issues of a social, political, and economic nature in the field of non-rocket industrialization of near space were discussed. The collection contains the reports by engineers, inventors, scientists, representatives of public organizations from Belarus, as well as from near and far abroad countries.

The publication is intended for specialists in the field of transport communications, employees of public administration bodies, research institutes, professors and students of educational institutions.

Scientific Publication

NON-ROCKET NEAR SPACE INDUSTRIALIZATION: PROBLEMS, IDEAS, PROJECTS

Collection of Articles of the IV International Scientific and Technical Conference
(September 18, 2021, Maryina Gorka)

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Cover design: N. Gorbunova

Visualizations and illustrations: O. Bykova, M. Siry, A. Koshelev, N. Gorbunova

The authors of the published articles are responsible for the accuracy of the information provided in them.

Materials from open Internet sources were used in the process of working on the publication.

Signed to the print on Jul/20/2022. Format 60 × 84 1/8. Enamel paper. Offset printing.
Conventional printed sheets 44.64. Circulation 300 copies. Order 1534.

State enterprise "StroyMediaProject".
Certificate of state registration of publisher, manufacturer, distributor of printed publications No. 1/43 of Oct/03/2013.
13/61 V. Khoruzhey Str., Minsk, 220123.

Printed at Polycraft LLC printing house.
Certificate of state registration of publisher, manufacturer, distributor of printed publications No. 2/14 of Nov/21/2013.
50, block 4, room 401a Knorina Str., Minsk, 220103.

UDC 629.78
ISBN 978-985-7172-75-7